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IMPRIMERIE A/S L. IHRICH

On Boric Acid in the Sea and its Influence on the Carbonic Acid Equilibrium.

By

Kurt Buch,

Thalassological Institute, Helsingfors, Finland.

1. Introduction.

In a recently published treatise on the geochemistry of boron V. M. Goldschmidt and Cl. Peters determine the boron content of sea water by spectrographical analysis as 30 g. B_2O_3 per $m.^3$ approximately, a content which is considerably larger than has hitherto been assumed. The view held up to the present is based on the statement made by L. Dieulafait in 1877 to the effect that the content is at least 0.2 g. B per $m.^3$. The above investigators, however, also quote an analysis by O. Bertrand and H. Agulhon in 1914, generally not cited in text books (probably because it is mentioned in a foot-note) but the result of which, viz., 31.7 g. B_2O_3 fully agrees with that of Goldschmidt and Peters. The relatively large quantity of boron naturally exercises an influence on various conditions in the sea. Many marine plants contain boron, and a physiological need of boron has already been proved also in the case of certain plant organisms (16, 17). The rôle of boron as a buffer is of special interest. The main buffer action is exerted by carbonic acid and carbonates, although it is possible that the equilibrium system of the latter can be, to a certain extent, influenced by boric acid and its salts, whereby the last-mentioned also participate in determining pH, in the interchange of carbonic acid with the atmosphere, in the solubility conditions of calcium carbonate, etc. The whole carbonic acid equilibrium system was recently put to an exhaustive experimental test by a Committee of the International Council, consisting of K. Buch, H. W. Harvey and H. Wattenberg, assisted by S. Gripenberg. It became necessary to explain the influence of boron on the carbonic acid system. This required, in the first place, an exact and comprehensive knowledge of the boric acid content. Above all, it was important to find out its possible fluctuations in various oceanic regions. In the second place a physico-chemical investigation of the equilibrium of boric acid with its ions

at different temperatures and chlorinities or, in other words, a determination of the apparent dissociation constant and its dependence on these factors became indispensable. Moreover, it was necessary to determine with respect to the carbonic acid system itself, which had been tested in water containing boric acid, to what extent the dissociation constants of carbonic acid determined by the International Committee were influenced by the boric acid content. As regards the first constant there was no doubt that it was not affected by boric acid as it was determined in such an acid pH range that the whole boric acid was present in an undissociated state and thus, practically, acted as a non-electrolyte. The second constant was, however, determined at alkaline pH values, wherefore an additional test of this quantity was necessary. A detailed discussion of this will be found in Section 3.

2. The Boric Acid Content of Sea Water.

Respecting the question of the quantity of boric acid in the sea fairly comprehensive experience has already been gained. Immediately after the investigation of Goldschmidt and Peters, quantitative analyses of samples of water taken in different regions were made by H. Wattenberg, of the "Institut für Meereskunde", Berlin, and by the author. But even prior to this, extensive series of analyses of water from different regions of the Pacific as well as the Atlantic Oceans were executed by E. G. Moberg and M. W. Harding, of "Scripps Institution", La Jolla, California. The results of the latter investigators as well as of Wattenberg have kindly been placed at the disposal of the author. As regards the investigations made in Helsingfors, only their results will be given here as the analyses themselves have already been published elsewhere (6); regarding the methods employed it may merely be added that the determinations were made titrimetrically, as were those in Berlin and La Jolla. The final procedure employed was tested with artificial sea water with the addition of known amounts of boric acid of the same concentration as occurs in sea water. The individual titration values (cm.^{3} barium hydroxide consumed) never differed more than 0.02 cm.^{3} from each other.

A list of the water samples investigated is given below, indicating the place of origin, longitude and latitude (as far as known), date of collection, as well as salinity and chlorinity. When samples of water are later referred to, only their general place of collection will be mentioned.

List of water samples.

Place of collection	Latitude	Longitude	Date	S‰	Cl‰
1. 20 nautical miles SW. of Hangö	59° 30′N.	22° 35′E.	1932 12 7	6.19	3.41
2. Cattegat No. 1	56° 16′	12° 25′	1932 12 9	12.47	6.89
3. Cattegat No. 2	57° 35′	11° 08′	1932 12 9	24.07	13.32
4. North Sea	55° 39′	4° 50′	1933 1 19	34.69	19.20
5. Plymouth	—	—	1931 2	35.03	19.39

The analyses are given in Table 1, showing 1) place of collection, 2) boric acid content expressed as grammes B_2O_3 per m.^{3} and also 3) in milli-equivalents per litre, 4) chlorinity, and 5) ratio of boron to chlorine, each expressed in grammes per 1 kg. of water. All the analyses were made by Mr. H. Miekk-Oja.

Table 1.

Place of collection	B_2O_3 g./m.^{3}	H_3BO_3 m.equiv./l.	Cl ‰	B ‰/Cl ‰
Plymouth	16.05	0.461	19.39	0.000250
	16.0	0.458		248
	15.9	0.455		246
North Sea	15.1	0.434	19.20	237
	15.0	0.431		236
Cattegat No. 2	10.3	0.295	13.29	236
	10.2	0.292		233
	10.1	0.289		231
Cattegat No. 1	5.4	0.156	6.87	243
	5.4	0.156		243
	5.3	0.153		239
20 nautical miles SW. of Hangö	2.75	0.079	3.41	249
	2.75	0.079		249
	2.65	0.076		240
	2.65	0.076		240

The last column in the table admits of a comparison between the results obtained in different laboratories. It will be found that the boron content, within the salinity amplitude (3.41 — 19.8 ‰ Cl) investigated, is proportional to the chlorine content.

The mean value for the analyses made in Helsingfors is B ‰ = 0.000241 Cl ‰. The Plymouth water had been collected two years previously and kept in a carboy possibly containing boron. The others were all fresh, only a few weeks old. The mean value for the freshly taken samples was 0.000240. The mean of the analyses made at "Scripps Institution", La Jolla, was 0.000239. The analyses at the "Institut für Meereskunde", Berlin, gave 0.000248, thus agreeing best with the Plymouth water. As far as the author knows, the water analysed in Berlin had also stood for a long time. Whether or not this slight increase in the boron content as compared with the fresh samples can be interpreted as an effect of the boron content of the glass cannot be determined. In any case it lies within the analytical errors which, owing to the small quantities, are liable to have a comparatively great influence, the greater the lower the chlorinity. For instance, the titration difference between the two values of the Hangö water (see Table 1) viz. 0.079 and 0.076 m.equiv./l. respectively (or B ‰/Cl ‰ = 0.000249 and 240) was only 0.01 cm.^{3}, the volume of the liquid being 200 cm.^{3}.

On the basis of the results we can express the boron content of sea water in relation to chlorinity as

$$B\ ‰ = 0.00024\ Cl\ ‰.$$

Thus for a water of 35 ‰, assuming its specific gravity to be 1.030, we get a boron content, expressed in the usual analytical measures, of B = 4.65 mg./l. = 0.43 m.equiv./l. or B_2O_3 = 15.0 mg./l. or g./m.^{3}.

This content, however, represents only half the mean content found by Goldschmidt and Peters. On the other hand, it is known that the spectrographical method does not give the same degree of accuracy as a volumetric analysis and, according to a private communication from Prof. Goldschmidt, some of his individual values range as low as these found here, so that this difference cannot be regarded as fundamental. As the chlorinity of sea water may practically be taken as a measure of its content of *marine* salts (according to which view, for instance, the brackish water from Hangö (see Table 1) of 3.41 ‰ contains about 17 % ocean water) the constant relation B/Cl found implies a corroboration of Goldschmidt's and Peter's geochemical result, to the effect that boron is a definite constituent of *sea* water and is definitely a "talassophile element".

3. The influence of Boric Acid on the Carbonic Acid Equilibrium in Seawater.

This question is closely connected with the long-discussed problem as to whether the buffer system of sea water, which determines its pH, contains, besides carbonic acid, other weak electrolytes also. The first to put forward a suggestion in this connection was Aug. Krogh, who even points to the possibility of the influence of boric acid (1904). However, taking into consideration all that was known at the time concerning boric acid in the sea, namely, Dieulafait's statement in 1877 mentioned above, one could hardly believe the influence of this acid to be appreciable. Other weak acids are, as far as is known, present in still lower concentrations. Nevertheless, the carbonic acid — carbonate system in sea water showed certain deviations from carbonate — bicarbonate solutions which could not then be satisfactorily explained by the theory of electrolytic dissociation.

In 1925 L. Irving published an experimental investigation of the neutralization curve of sea water. This differs decidedly in the alkaline region from the corresponding curve for a carbonate—bicarbonate solution. At pH between 8 and 8.4, the upper limit in sea water, the difference in pH between these systems for the same total carbonic acid content is 0.13 units approximately. In a further discussion of the question the author (5) showed that a good deal of this difference can be attributed to the influence of neutral salts. According to Michaelis, a hydrogen element consisting, for instance,

of 0.001 n HCl in one electrode vessel and 0.001 n HCl + 1 n KCl in the other, generates an electromotive force of 2.5 millivolts approximately, owing to the fact that it depends on the hydrogen-ion activity, not on the total concentration. The former is less in the vessel containing the neutral salt. A similar effect is produced by the neutral salts in sea water, and the difference in pH between sea water and distilled water arising therefrom was estimated at 0.06 units approximately. That which, on deducting this value, remains of the difference stated by I r v i n g, the author believed to be attributable to the influence of other weak acids, which assumption has now been confirmed. In the author's earlier investigations of the carbonic acid system as well as those of the above-mentioned International Committee the determinations of the second dissociation constant of carbonic acid were subject to the influence of boric acid. The author estimated it at $pK'_2 = 9.05$ for artificial, boric acid-free sea water of 35 ‰ salinity and 20° C. temperature. The Committe obtained 8.8 for sea water. D. M. G r e e n b e r g and E. G. M o b e r g had found 9.0, but whether in natural or artificial water is not known to the author. The Committee discussed the causes of this difference, but decided to leave the clearing up of this question for the time being, pending a later investigation. The constant actually found for natural sea water was used as the basis for the calculation of the total carbonic acid content, the tension and the other carbonic acid constituents. The experimental foundation for the carbonic acid system consisted of determinations of the CO_2-tension, pH, total carbonic acid and alkali reserve in natural sea waters. If their interdependence had been established in a purely empirical manner, the result would be independent of the presence of other weak electrolytes. However, as the determinations purported to establish the dissociation constants of carbonic acid, they had to be made in a pH range in which the most exact values possible could be expected. In the case of pK'_2 this favourable pH range was higher than that occurring in the sea (between 8.5 and 9.2). Within this pH range the constant found for sea water, the value of which is, of course, influenced by boric acid but which can be regarded as a practical working constant, gives correct values for the calculated carbonic acid content, but, on departing from this range towards more acid pH values, one encounters increasing differences which disappear again, however, at still lower values (below $pH = 7.5$). The last-mentioned circumstance depends on the fact that in this acid range the concentration of the carbonate ions becomes insignificant and the second dissociation constant exercises no further influence. The difference between the total carbonic acid content calculated with the aid of the tables drawn up by the Committee and that found in the present investigation taking boric acid into consideration, amounts for ordinary salinities in the most unfavourable case to 2.5 %, which difference approximates to the limits of error for the determination. If the difference is calculated in pH for the same total carbonic acid, then the greatest deviation will be 0.08 units

approximately, or almost exactly the value derived from Irving's work on deducting the neutral salt effect. However, when we know the total boric acid content of sea water and the apparent dissociation constant of boric acid, the effect of boric acid can be determined and the various constituents of the carbonic acid system may then be calculated essentially in the way indicated by the International Committee, viz., at a given temperature and Cl $^0/_{00}$, from the experimentally determined values of pH and the alkali reserve. The dissociation constants of carbonic acid should of course be correct, i. e., determined in water free from borate ions. With regard to K'_1 this is attained by working in an acid pH range, as mentioned above. In the case of K'_2 there was no other possibility but to make a new determination in *boron-free artificial* water. (See section 4). The influence of boron on the CO_2-system consists in the borate ions participating in the alkali reserve. It has been assumed up to the present that the latter is practically made up of base equivalents corresponding to the ions of carbonic acid. In reality it is made up of base equivalents corresponding to both the carbonic and the boric acids. As the concentration of the borate ions and, with it, a corresponding base equivalent, which may be called borate alkalinity, vary with pH, the remainder of the alkalinity, i. e., the carbonate-alkalinity, varies also. The latter may be expressed by the equation:

$$(1) \qquad 2c_{CO''_3} + c_{HCO'_3} = \text{carbonate alkalinity.}$$

The sum of both alkalinities is almost identical with the total alkalinity, which is practically constant for a given water and may be determined titrimetrically by determining the so-called alkali reserve. The following equation expressing the relation between positive and negative ion equivalents is exactly valid for an aqueous solution containing carbonates and borates in the presence of free carbonic acid and boric acid.

$$(2) \qquad \text{Total alkalinity} = 2c_{CO''_3} + c_{HCO'_3} + c_{H_2BO'_3} + c_{OH'}$$

$$= \text{alkali reserve} + c_{H\cdot}$$

If we take into consideration that

$$c_{OH'} \cdot c_{H\cdot} = \text{Kw} = \text{the ion product of water}$$

we obtain

$$(3) \qquad \text{Carb. alk.} = \text{Alkali reserve} - c_{H_2BO'_3} + \left(c_{H\cdot} - \frac{Kw}{c_{H\cdot}}\right)$$

The term in brackets has to be taken into consideration only in alkaline solutions (pH > 8.5).

In order that the alkali reserve, determined titrimetrically, may indicate with the greatest possible exactitude the total alkalinity, it is important to titrate to the correct pH exponent in other words, to choose a suitable indicator. The object of the titration is really to

add a quantity of strong acid, preferably HCl, equivalent to the bases, whereby these are transformed into chlorides. In practice a surplus of hydrochloric acid is added, the carbonic acid removed by boiling and the surplus determined with barium hydroxide solution. We should then titrate to such a pH that the boric acid is still present in an entirely undissociated form. We can calculate at what pH this is the case. If we assume that the boric acid diss. constant is equal to 10^{-9} and the total boric acid concentration $= 10^{-3}$, the boric acid diss. equation gives us:

$$\frac{c_{H^\cdot}{}^2}{10^{-3}} = K_B = 10^{-9}$$

or

$$c_{H^\cdot} = \sqrt{10^{-12}} = 10^{-6}$$

We should thus titrate to about pH 6, but not in any case to a more alkaline reaction (for instance with phenolphthalein) as part of the boric acid is then transformed into borate, which will not be determined, and we obtain an alkalinity figure which is too low. A suitable indicator for this purpose is methyl red. A still more sensitive one is a mixture of methyl red and cresol green, which has been introduced by Wattenberg for determining the alkali reserve of sea water. The transformation point of both indicators is in fact a little more acid, viz., quite near pH 5, but the error caused by this may be ignored. We may now use all the equations presented in the Report of the International Committee without alteration other than substituting carbonate alkalinity for alkali reserve (titration alkalinity) and introducing the new values for K'_2. Nevertheless, the system is unfortunately complicated by the unavoidable fact that a new variable has been introduced with the boric acid, as the carbonate alkalinity is not a constant, like the alkali reserve, but has to be calculated for each pH.

In the following sections there will be given at first determinations of the second diss. constant of carbonic acid, then determinations of the boric acid constant and, lastly, directions for the calculation of the different carbonic acid constituents, in which the boric acid has been considered.

4. Determinations of K'_2.

These determinations were made by means of parallel determinations of pH and the total carbonic acid content $c_{\Sigma CO_2}$ in boron-free artificial water, with a varying salt content and titration alkalinity at a temperature of 20°. The artificial water was made up according to Brujewicz's (20) method, substituting NaCl for NaBr and $CaCl_2$ for $CaCO_3$. Four different waters were used. Their salt contents were selected in accordance with the salinities of the natural waters (Table 1) in which the boric acid content had been determined and which were also used later for determining the dissociation constant

of boric acid. The determinations of the alkali reserve and H-ions were made by Mr. H. Miekk-Oja. The former was determined according to Wattenberg's method, and the latter spectro-photometrically with cresol red as indicator according to Buch. (2, 3, 4.) The pH range within which the measurements were made is situated at the upper end of the transformation curve of the indicator, whereby the pH measurements became somewhat uncertain. Another indicator would have been more suitable in this case. But, as the pH of sea water is generally measured with this indicator, it was retained mainly in order to avoid possible systematic errors which may have arisen from the fact that the salt errors vary for different indicators and must be found for each individual indicator. The total carbonic acid content was determined with Otto Pettersson's apparatus. The results were calculated according to Equation 37 of the Report of the International Committee:

$$(4) \qquad K'_2 = a_{H\cdot} \frac{\left(1 + \frac{a_{H\cdot}}{K_{c_1}}\right)\left(\text{alk. reserve} + a_{H\cdot} - \frac{Kw}{a_{H\cdot}}\right) - c_{\Sigma CO_2}}{2c_{\Sigma CO_2} - \text{alk. reserve} - a_{H\cdot} + \frac{Kw}{a_{H\cdot}}}$$

where K_{c_1} og K'_2 indicate the first and second dissociation constants of carbonic acid[1]). The analytical material as well as the dissociation constants, derived from it and expressed in terms of their negative logarithms pK'_2 are given in Table 2. The various columns contain: 1) consecutive number, 2) the chlorinity, 3) the negative logarithm, pH, of the hydrogen ions (S. P. L. Sörensen's conventional value) corrected for the salt error according to Ramage and Miller, 4) titration alkalinity in milli-equivalents per litre, 5) total carbonic acid in millimol. per litre. Then follow the calculated quantities: 6) $1 + \frac{a_{H\cdot}}{K_{c_1}}$, the value for K_{c_1} being taken from the Report to the International Committee, 7) the difference between OH and H-ions, 8) pK'_2.

An equation relating the pK'_2 values obtained to the chlorinity has been calculated by the method of least squares, using as zero value (= the thermodynamic constant for 20°) $pK_2 = 10.45$, which was adopted by the International Committee as most reliable.

$$(5) \qquad pK'_2 = 10.45 - 0.682 \sqrt[3]{Cl\ ‰} + 0.020 \cdot Cl\ ‰. \qquad t = 20°.$$

The equation is presented graphically in Fig. 1. For a normal ocean water of 35 ‰ (Cl = 19.4 ‰) one obtains $pK'_2 = 9.00$.

An approximate determination — also with artificial water — had previously been made by the author (5), when the value 9.05 was obtained. A recalculation, using the complete equation (4), instead of

[1]) $K_{c_1} \frac{a_{H\cdot} \cdot c_{HCO'_3}}{c_{CO_2}}$, $K'_2 = \frac{a_{H\cdot} \cdot c_{CO''_3}}{c_{HCO'_3}}$, see Report (8) p. 11, 12.

Table 2.

No.	Cl ‰	pH	Titr. alk. m.equiv./l.	ΣCO_2 m.mol. l.	$\frac{1}{K_{C_1}}$	$\frac{a_H}{K_{C_1}}$	$\left(\frac{Kw}{a_H} - a_H\right) \cdot 10^3$	pK'_2
1	3.44	8.435	1.413	1.317	1.006	0.003		9.52
2	—	8.435	—	1.310	6	3		9.485
3	—	8.60	—	1.262	4	4		9.46
4	—	8.60	—	1.261	4	4		9.47
5	—	8.61	—	1.221	3	5		9.45
6	6.89	8.34	1.637	1.499	6	2		9.31
7	—	8.46	—	1.460	5	3		9.31
8	—	8.465	—	1.453	5	3		9.29
9	13.33	8.235	2.025	1.814	5	4		9.10
10	—	8.235	—	1.807	5	2		9.09
11	—	8.491	—	1.710	3	2		9.13
12	19.44	8.46	2.329	1.906	3	3		9.00
13	—	8.455	—	1.908	3	3		9.005
14	—	8.46	—	1.879	3	3		8.96
15	—	8.61	—	1.838	2	4		9.05
16	—	8.605	—	1.769	2	4		8.94
17	—	8.565	—	1.800	2	4		8.95
18	—	8.445	—	1.934	3	3		9.03
19	—	8.44	—	1.942	3	3		9.04

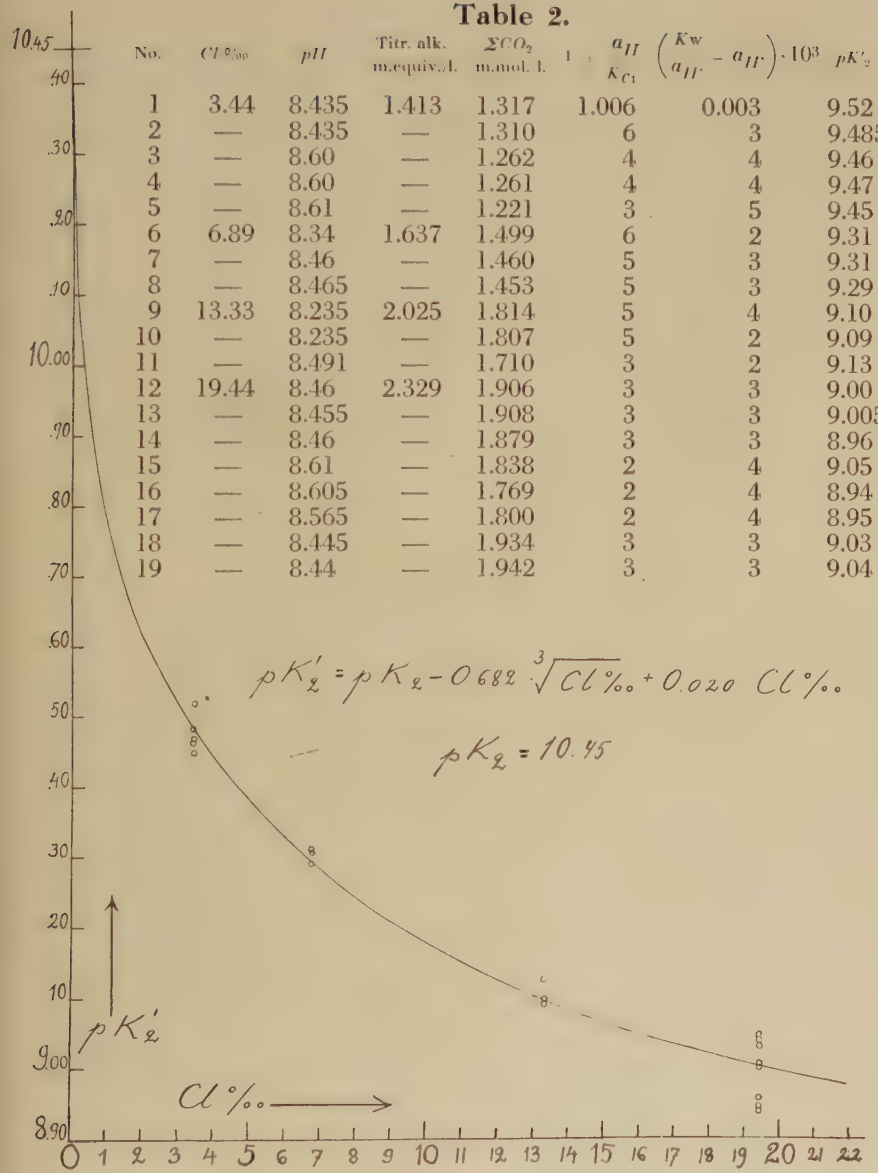

Fig. 1.

the simplified one used before, and eliminating a number of determinations in which the proportion between carbonates and bicarbonates was too unfavourable to give reliable values, resulted in the identical value, 9.00. As already mentioned, the same value was obtained by Greenberg and Moberg, wherefore this constant can be regarded as reliably determined. The mean error amounts to $= \pm 0.03$.

Table 3.

pK'_2 at various temperatures and chlorinities.

t° / Cl ‰	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
0	10.68	.66	.63	.61	.58	.56	.54	.51	.49	.47	.45	.42	.40	.38	.36	.34
1	10.02	9.99	.97	.94	.92	.90	.87	.85	.83	.81	.78	.76	.74	.72	.70	.68
2	9.87	.84	.81	.79	.77	.74	.72	.70	.67	.65	.63	.61	.59	.56	.54	.52
3	9.76	.73	.71	.68	.66	.64	.61	.59	.57	.55	.52	.50	.48	.46	.44	.42
4	9.68	.65	.63	.60	.58	.56	.53	.51	.49	.47	.44	.42	.40	.38	.36	.34
5	9.62	.59	.56	.54	.52	.49	.47	.45	.42	.40	.38	.36	.34	.32	.29	.27
6	9.56	.54	.51	.49	.46	.44	.42	.39	.37	.35	.33	.30	.28	.26	.24	.22
7	9.52	.49	.46	.44	.42	.39	.37	.35	.32	.30	.28	.26	.24	.22	.19	.17
8	9.48	.45	.42	.40	.38	.35	.33	.31	.28	.26	.24	.22	.20	.18	.15	.13
9	9.44	.41	.39	.36	.34	.32	.29	.27	.25	.23	.21	.18	.16	.14	.12	.10
10	9.41	.38	.36	.33	.31	.29	.26	.24	.22	.20	.17	.15	.13	.11	.09	.07
11	9.38	.36	.33	.31	.28	.26	.24	.21	.19	.17	.15	.12	.10	.08	.06	.04
12	9.36	.33	.31	.28	.26	.24	.21	.19	.17	.14	.12	.10	.08	.06	.04	.02
13	9.34	.31	.29	.26	.24	.21	.19	.17	.14	.12	.10	.08	.06	.04	.02	.00
14	9.32	.30	.27	.24	.22	.20	.17	.15	.13	.11	.09	.07	.04	.02	.00	8.98
15	9.30	.27	.25	.22	.20	.18	.15	.13	.11	.09	.06	.04	.02	.00	8.98	.96
16	9.28	.26	.23	.21	.18	.16	.14	.11	.09	.07	.05	.02	.00	8.98	.96	.94
17	9.27	.24	.22	.19	.17	.14	.12	.10	.08	.05	.03	.01	8.99	.97	.95	.93
18	9.26	.23	.20	.18	.15	.13	.11	.09	.06	.04	.02	.00	8.97	.95	.93	.91
19	9.24	.21	.19	.16	.14	.12	.10	.07	.05	.03	.01	8.98	.96	.94	.92	.90
20	9.23	.20	.18	.15	.13	.11	.08	.06	.04	.02	8.99	.97	.95	.93	.91	.89
21	9.22	.19	.17	.14	.12	.10	.07	.05	.03	.01	8.98	.96	.94	.92	.90	.88
22	9.21	.19	.16	.14	.11	.09	.06	.04	.02	.00	8.97	.95	.93	.91	.89	.87

5. K'_2 at Different Temperatures.

Concerning the question of the dependence of K'_2 on temperature the results arrived at by the International Committee hold good without any alteration. A new table of pK'_2 at different temperatures and chlorinities was drawn up in the way indicated by the Committee (page 53) using the same values for the thermodynamic constant (table 12, page 14) at different temperatures.

6. Activity of the Carbonate Ions.

A further consequence of the change in K'_2 is that the activity of the CO''_3 ions, important in the question of the calcium carbonate solubility in the sea, has to be recalculated. In the following Table 4, in the same manner as in the Report of the Committee and using the same values for the thermodynamic constant, new values for the activity coefficient of the CO''_3 ions, $f_{CO''_3}$, have been calculated. Besides the values of $f_{CO''_3}$ for different salinities the table also contains their negative logarithms $pf_{CO''_3}$.

Table 4.

Cl ‰	2	4	6	8	10	12	14	16	18	20	22
$pf_{CO''_3}$	1.03	1.275	1.43	1.55	1.64	1.71	1.76	1.82	1.86	1.90	1.93
$f_{CO''_3}$	0.093	0.054	0.037	0.029	0.023	0.020	0.017	0.015	0.014	0.013	0.012

7. Determination of the Borate-ion Concentration and the apparent Dissociation Constant of Boric Acid.

The analytical determinations necessary for calculating the borate-ion concentration and the dissociation constant of boric acid when pK'_2, and the total boric acid content are known, are the same as those for pK'_2, viz., determinations of alkali reserve, total carbonic acid and pH. The previously mentioned water sample from Hangö, two samples from the Cattegat and freshly obtained water from the North Sea were used for the investigation. The first tests were made with the waters in their natural condition. It was soon found, however, especially in the case of the waters with the lowest salinities, that the boric acid concentration was too low to give reliable values for the $H_2BO'_3$ ions to be used in calculating the diss.-constant. The author was then obliged to add a small amount of buffer mixture to each water sample, for which purpose two of P a l i t z s c h's buffer solutions with pH = 8.84 and 8.95 were used. The hydrogen-ion concentration could be varied slightly by passing carbon dioxide-free air through the water for varying lengths of time before the addition. The addition amounted to 25 cm.^{3} per 1 litre of water. The resulting alkalinity was then made up of the sum of the original alkalinity and the alkali content of the added borax—boric acid mixture, and the resulting total boric acid content consisted, likewise, of the original + that of the buffer. The total electrolytic content was somewhat changed

through the addition, which was also taken into consideration. This method is a little uncertain, as one cannot definitely state whether or not there is an appreciable concentration of polyborate ions in the water. However, this is practically of no consequence, as the total concentrations were very low (about 0.005 mol./l. boric acid) and the variations in concentration and pH very limited so that no appreciable displacement of the equilibrium could occur. The constant derived becomes rather a working constant and we have to interpret $c_{H_2BO'_3}$, as the sum of all the different borate ions.

The calculation of the borate-ion concentration and the dissociation constant of boric acid was made by solving Equation 3 in respect of $c_{H_2BO'_3}$.

$$(6) \qquad c_{H_2BO'_3} = \text{Alkali reserve} - \text{carbonate alk.} + \left(c_{H\cdot} - \frac{Kw}{c_{H\cdot}}\right)$$

For the alkali reserve the experimental value was taken. The carbonate alkalinity was again obtained by using the analysis of total carbonic acid and pH in solving Equation 48a (Report of the International Committee) in respect of the alkali reserve, the latter being identical with the carbonate alkalinity, when the correct value for K'_2 is used.

$$(7) \qquad \text{Carb.alk.} = c_{\Sigma CO_2} \frac{\left(1 + \frac{2K'_2}{a_{H\cdot}}\right)}{\left(1 + \frac{a_{H\cdot}}{K_{c_1}} + \frac{K'_2}{a_{H\cdot}}\right)} = c_{\Sigma CO_2} \cdot f$$

In the latter equation f indicates the relation between the terms in brackets. As already mentioned, the bracketed term in Equation 3 containing the hydrogen-ion concentration $c_{H\cdot}$ may be ignored for pH < 8.5. For lower $c_{H\cdot}$-values the num. log of Sörensen's pH ($a_{H\cdot}$) was introduced, which, of course, is not identical with $c_{H\cdot}$, but the difference is so small that it may be neglected. Thus we finally obtain the following expression for $c_{H_2BO'_3}$:

$$(8) \qquad c_{H_2BO'_3} = \text{Alkali reserve} - c_{\Sigma CO_2} \cdot f + \left(a_{H\cdot} - \frac{Kw}{a_{H\cdot}}\right)$$

where the value of f is derived from Equation 7. After the borate-ion concentration had been determined, the dissociation constant of boric acid was deduced from the equation

$$(9) \qquad \frac{a_{H\cdot} \cdot c_{H_2BO'_3}}{c_{H_3BO_3}} = \frac{a_{H\cdot} \cdot c_{H_2BO'_3}}{c_{\Sigma H_3BO_3} - c_{H_2BO'_3}} = K'_B$$

The results obtained at 20° are given in Table 5, the columns of which contain: 1) consecutive numbers, 2) salinity ‰ of the water sample, the buffer addition being considered, 3) the corresponding chlorinity obtained from the equation Cl = S/1.805, 4) total alkalinity (= alkali reserve) m.equiv./l. representing the sum of the initial alkalinity of the water and that of the buffer, 5) total carbonic acid in m.mol./l., 6)

total boric acid m.mol./l., 7) pH; 8) and 9) values used for pK_{c_1} and pK'_2 10) the borate-ion concentrations calculated from Equation 8, and 11) the dissociation constants in terms of their negative logarithms pK'_B calculated from Equation 9.

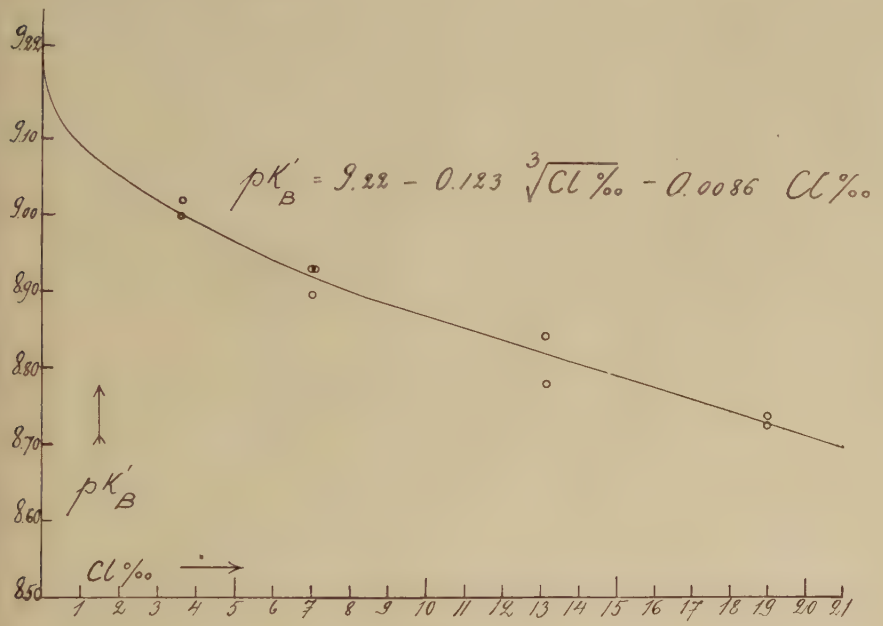

Fig. 2.

Table 5.

No.	S‰	Cl‰	Total alk. m.equiv./l.	ΣCO_2 m.mol./l.	ΣH_3BO_3 m.equiv./l.	pH'	pK_{c_1}	pK'_2	$c_{H_2BO'_3}$	pK'_B
1	2	3	4	5	6	7	8	9	10	11
1	6.46	3.56	3.137	1.406	4.954	8.66	6.19	9.47	1.544	9.00
2	»	»	3.328	1.288	»	8.80	»	»	1.807	9.04
3	12.6	6.93	3.343	1.329	5.029	8.645	6.12	9.29	1.769	8.93
4	»	»	3.534	1.573	»	8.63	»	»	1.682	8.93
5	»	»	3.534	1.574	»	8.60	»	»	1.693	8.89
6	23.8	13.2	3.715	1.721	5.163	8.465	6.03	9.10	1.673	8.78
7	»	»	3.907	1.742 1.760	»	8.555	»	»	1.771	8.84
8	34.4	19.0	4.013	1.885 1.883	5.300	8.425	5.97	9.01	1.743	8.74
9	»	»	4.204	2.023	»	8.43	»	»	1.764	8.73

From the values obtained an equation for the relation between Cl ‰ and pK'_B was calculated, as for pK'_2, by the method of least squares, where $6.0 \cdot 10^{-10}$ (or $pK_B = 9.22$) derived from Lundén's determinations, ($5.8 \cdot 10^{-10}$ for 18°, and $6.6 \cdot 10^{-10}$ for 25°) was used as zero value.

(10) $pK'_B = 9.22 - 0.123 \sqrt[3]{\text{Cl }^0/_{00}} - 0.0086 \text{ Cl }^0/_{00}$

or

(10a) $pK'_B = 9.22 - 0.10 \sqrt[3]{\text{S }^0/_{00}} - 0.00475 \cdot \text{S }^0/_{00}$

The equation is presented graphically in Fig. 2. The curve is practically rectilinear for Cl $^0/_{00}$ = 8 to 19. The fact that the third term is negative means a decrease for higher chlorine content, which, however, cannot be theoretically supported; on the contrary, one would expect the curve to rise. This may perhaps be regarded as an indication of the above-mentioned possibility of the presence of a certain amount of polyborate ions, the concentration of which may change with increasing electrolytic content. On the other hand, the low value of the constant, 0.0086, and, consequently, its slight influence on the curve confirm the supposition that the polyborate formation is of secondary importance.

8. K'_B at Different Temperatures.

In order to draw up a table on the dissociation constant of boric acid at different chlorinities and temperatures, like that for carbonic acid, a knowledge of the temperature function also is required. Theoretically the temperature function may even vary slightly with the chlorinity. As this variability, however, is of no importance (compare in this connection the discussion in the Report of the International Committee) and the total concentration of boric acid is slight, we may ignore it and assume for all chlorinities the same dependence on temperature which was experimentally found by H. Lundén for the thermo-dynamic constant. Starting from the following values determined by Lundén for the dissociation constant of boric acid: $K_{15}° = 5.48 \cdot 10^{-10}$, $K_{25}° = 6.62 \cdot 10^{-10}$ and $K_{40}° = 8.49 \cdot 10^{-10}$ and his equation for the heat of dissociation[1]) calculated on the basis of these figures, the following values for the thermo-dynamic constant were derived:

t°	0	5	10	15	18	25	40
$K_B \cdot 10^{10}$	4.04	4.51	4.98	5.48	5.81	6.62	8.49

The values for 15°, 25° and 40° are Lundén's original ones, that for 18° Lundén's interpolation, those for 0°, 5° and 10° calculated. A table for equidistant temperatures was graphically interpolated on the basis of these values. Combined with the values obtained for equidistant chlorinities with the aid of Equation 10, this led to Table 6 containing the dissociation constant of boric acid at different temperatures and chlorinities expressed in terms of the negative logarithm pK'_B.

The object of the determination of the boric acid constant, viz., calculation of the borate-ion concentration in a water of given temperature and Cl $^0/_{00}$, is now attained by introducing the

[1]) qdiss — 3.260 + 12 t° g. kal.

Table 6.

pK'_B at various temperatures and chlorinities.

t° Cl‰	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
0	9.39	.38	.36	.34	.32	.30	.29	.27	.25	.24	.22	.20	.19	.17	.16	.14
1	9.26	.24	.22	.20	.19	.17	.15	.14	.12	.10	.09	.07	.05	.04	.02	.01
2	9.22	.20	.18	.17	.15	.13	.11	.10	.08	.06	.05	.03	.01	.00	8.98	.97
3	9.19	.17	.15	.14	.12	.10	.08	.07	.05	.03	.02	.00	8.98	.97	.95	.94
4	9.16	.14	.13	.11	.09	.07	.06	.04	.02	.01	8.99	.97	.96	.94	.93	.91
5	9.14	.12	.10	.08	.07	.05	.03	.01	.00	8.98	.97	.95	.93	.92	.90	.89
6	9.12	.10	.08	.06	.05	.03	.01	8.99	.98	.96	.94	.93	.91	.90	.88	.87
7	9.10	.08	.06	.04	.03	.01	8.99	.97	.96	.94	.92	.91	.89	.88	.86	.85
8	9.08	.06	.04	.02	.01	8.99	.97	.95	.94	.92	.91	.89	.87	.86	.84	.83
9	9.06	.04	.02	.00	8.99	.97	.95	.94	.92	.90	.89	.87	.85	.84	.82	.81
10	9.04	.02	.01	8.99	.97	.95	.93	.92	.90	.88	.87	.85	.84	.82	.81	.79
11	9.03	.01	8.99	.97	.95	.93	.92	.90	.88	.87	.85	.83	.82	.80	.79	.77
12	9.01	8.99	.97	.95	.93	.92	.90	.88	.87	.85	.83	.82	.80	.79	.77	.76
13	8.99	.97	.96	.94	.92	.90	.89	.87	.85	.83	.82	.80	.79	.77	.76	.74
14	8.98	.96	.94	.92	.90	.89	.87	.85	.84	.82	.80	.79	.77	.76	.74	.73
15	8.96	.94	.92	.91	.89	.87	.85	.84	.82	.81	.79	.77	.75	.74	.72	.71
16	8.95	.93	.91	.89	.87	.86	.84	.82	.81	.79	.77	.76	.74	.72	.71	.70
17	8.93	.91	.89	.88	.86	.84	.82	.81	.79	.77	.76	.74	.72	.71	.69	.68
18	8.92	.90	.88	.86	.84	.83	.81	.79	.78	.76	.74	.73	.71	.70	.68	.67
19	8.90	.88	.87	.85	.83	.81	.79	.78	.76	.74	.73	.72	.70	.68	.67	.65
20	8.89	.87	.85	.83	.81	.80	.78	.76	.75	.73	.71	.70	.68	.67	.65	.64
21	8.88	.86	.84	.82	.80	.78	.77	.75	.73	.72	.70	.68	.67	.65	.64	.62
22	8.86	.84	.82	.81	.79	.77	.75	.74	.72	.70	.69	.67	.65	.64	.62	.61

corresponding value from Table 6 into Equation 9 and solving it in respect of $c_{H_2BO'_3}$. The total boric acid entering in this equation may be calculated from the equation B $^0/_{00}$ = 0.00024 Cl $^0/_{00}$.

9. Calculation of the Various Carbonic Acid Constituents.

All constituents are calculated according to the equations given in the Report of the International Committee (Chapter VIII, p. 56), in which, instead of the alkali reserve, the carbonate alkalinity is used. The latter is found from Equation 6, in which the quantity within brackets may generally be omitted (for pH values below 8.5) and the borate-ion concentration, $c_{H_2BO'_3}$, is calculated as indicated in Section 8

$$\text{Carbonate alkalinity} = \text{Titr. alk.} - c_{H_2BO'_3};$$

the new values for pK'_2 should be used. The quantities $k_{HCO'_3}$ and $k_{CO''_3}$ have the same significance as in the Report of the Committee, and are found in the same way from Table 19 of the Report, which is not affected by the change in pK'_2.

The values obtained after introduction of the correction for boric acid are mostly somewhat higher than those calculated according to the method used in the Report of the Committee. However, in some cases lower values may also occur. The deviations increase — also in percentage — with increasing salinity. A simple system of corrections, valid for all temperatures and salinities, cannot be given. The carbonic acid tension and the free carbonic acid likewise increase by amounts lying almost within the limits of analytical error. A statement (6,7), founded on preliminary approximate calculations, to the effect that the deviations lie entirely within the analytical errors proved not to be quite correct. Table 7 gives an idea of the differences found for a 35 $^0/_{00}$ water at 20°.

Table 7.

Total carbonic acid and CO_2 tension calculated with ("corr.") and without ("uncorr.") correction for boric acid. Cl = 19.5 $^0/_{00}$, t = 20°.

pH	ΣCO_2 m.mol./l.			pCO_2 Atm. × 10^{-4}		
	corr.	uncorr.	diff.%	corr.	uncorr.	diff.
7.6	2.33	2.30	1.3	14.9	14.3	0.6
7.8	2.25	2.21	1.8	8.9	8.4	0.5
8.0	2.15	2.10	2.4	5.2	4.8	0.4
8.2	2.03	1.98	2.5	3.0	2.6	0.4
8.4	1.88	1.84	2.2	1.6	1.4	0.2

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Note on the Effect of Salts in the Determination of Phosphate in Sea Water by Denigès' Method.

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THE coeruleomolybdic method of Denigès for the estimation of dissolved phosphate in sea water, as first applied by Atkins (J. Mar. Biol. Assoc. Vol. XIII, No. 3), is now in general use. In stating the results, usually expressed as mg. P_2O_5 per cubic metre, no allowance is made for the effect of other salts present in sea water. Buch found that with an ocean water of 35 $^0/_{00}$ salinity the salts gave rise to an error in the estimation, the quantity of phosphate being some 20 $^0/_0$ too little (Cons. Perm. Int. pour l'Explor. de la Mer. — Rapp. et Proc.-Verb. Vol. LIII. 1928). His estimations were made by means of a spectrophotometer, using red light.

The following investigation was made in order to determine the error due to salts when the colours are compared visually in white light, and when the quantities of phosphate present are very small.

A sample of sea water of 35 $^0/_{00}$ salinity was obtained and found to contain 8.4 mg. P_2O_5 per cubic metre and to portions of this were added varying quantities of phosphate. The colour comparisons were made by means of Hehner tubes when there was more than 50 mg. P_2O_5 per cubic metre and the correction for the blue colour inherent in the water (J. Mar. Biol. Assoc. May, 1930) was applied. When less than 50 mg. P_2O_5 per cubic metre was present 60 cm. tubes were used (Harvey. Rapp. et Proc.-Verb. Vol. LIII. 1928).

The values obtained for sea water of salinity 35 $^0/_{00}$, collected during May in the English Channel, and containing 8.4 mg. of phosphate per cubic metre, expressed as P_2O_5, are shown in Table I. The values obtained with the same water diluted with an equal volume of distilled water are shown in Table II. These are expressed

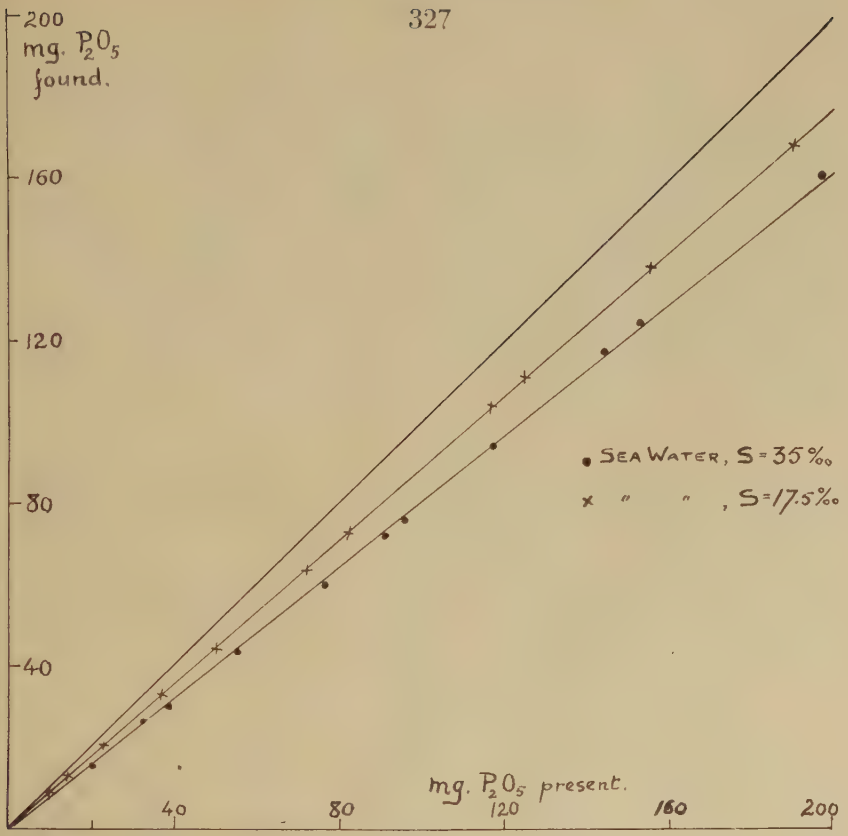

Figure 1.

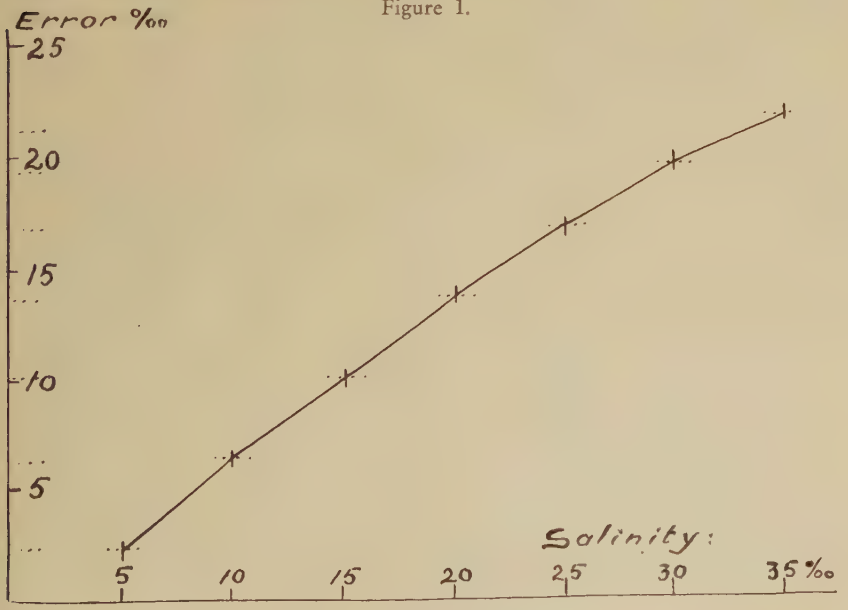

Figure 2.

graphically in Fig. 1 from which it will be seen that over a large range of concentration the salt error is dependent of the phosphate concentration and is at least approximately proportional to the salinity.

This conclusion was shown to apply rigidly by the following experiment. Sea water of salinity 35 $^0/_{00}$ was adjusted to a phosphate concentration of about 100 mg. P_2O_5 per cubic metre. Samples of lower salinity were made from this and re-adjusted to about 100 mg. P_2O_5 per cubic metre in each case. The precise figures are shown in Table III, from which it will be seen that percentage salt errors of the determinations made against a 100 mg. standard in distilled water were linearly proportional to the salinity (cf. Fig. 2).

Table I.

Sea water collected in the English Channel, May 1931. Salinity 35 $^0/_{00}$. Dissolved phosphate 8.4 plus 20 $^0/_0$ or 10 mg. P_2O_5 per cubic metre.

mg. P_2O_5 per cubic metre.

P_2O_5 added	Total P_2O_5 present	Total P_2O_5 found	Difference	Percentage error
9.9	19.9	14.8	5.1	25.1
22.5	32.5	26.2	6.3	19.3
28.5	38.5	30.4	8.1	21.0
45.0	55.0	42.6	12.4	22.5
67.8	77.8	60.1	18.7	24.0
81.0	91.0	72.6	18.4	20.2
85.5	95.5	76.9	18.6	19.4
108.0	118.0	93.9	24.1	20.4
135.0	145.0	118.8	26.2	18.0
142.5	152.5	125.8	26.7	17.5
187.9	197.9	162.9	35.0	17.6

Mean percentage error = 20.4.

Table II.

The same sea water diluted to 17.5 $^0/_{00}$ Salinity with distilled water.

P_2O_5 added	Total P_2O_5 present	Total P_2O_5 found	Difference	Percentage error
4.9	9.9	9.3	0.6	6.0
9.2	14.2	12.6	1.6	11.3
18.0	23.0	20.4	2.6	11.3
31.7	36.7	31.9	4.8	13.0
45.0	50.0	42.6	7.4	14.8
67.6	72.5	63.2	9.3	12.8
77.0	82.0	72.6	9.4	11.4
112.5	117.5	106.6	10.9	9.2
120.0	125.0	112.5	12.5	10.0
154.0	161.0	144.3	16.7	10.3
186.0	191.0	169.1	21.9	11.4

Mean percentage error = 11.0.

Table III.

Salinity ‰	P_2O_5 present	P_2O_5 found	Error %
35	105	82.2	21.7
30	104	83.4	19.8
25	103.5	85.9	17.0
20	102.8	88.5	13.9
15	102	91.7	10
10	101.4	94.8	6.5
5	100.7	98.5	2.1

The author is indebted to Mr. H. W. Harvey for suggesting the topic and his interest in the work.

Preservation of Sea Water Samples with Fluoride for Phosphate Estimation by Denigès' Method.

By

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WHEN sea water samples are stored without previous sterilisation (as Matthews and Atkins have already noticed) the quantity of dissolved phosphate often decreases.

In one experiment I found that the phosphate content of a sea water sample was reduced from 36 to 7 mg. P_2O_5 per cubic metre by one month's exposure to light, which facilitates the growth and multiplication of the plankton. The decrease in phosphate is less in water stored in darkness.

On the contrary, death and subsequent bacterial decay of such micro-organisms may actually lead to a substantial increase in phosphate. Moreover, the alkalinity of sea water may lead to solution of phosphate from the glass storage bottles. Thus phosphate determinations will be in error unless carried out within a short time of collection or unless planktonic activity is stopped by some method which does not interfere with the analysis. Furthermore, insoluble glass storage bottles must be employed (Christiania bottles).

Mercuric chloride, usually an excellent antiseptic, cannot here be used since it forms an opalescence with the stannous chloride reagent, which interferes with the comparison of the blue colours. Two drops of a 2.5 % mercuric chloride solution is enough to produce an opalescence in 100 $cm.^3$ of water due to the formation of mercurous chloride when the stannous chloride is added.

The standard solution of phosphate may be kept indefinitely in the presence of a little sulphuric acid. Nevertheless when sulphuric acid is added to sea water the quantity of dissolved phosphate may increase due to the hydrolysis of organic phosphorus compounds present in the water.

The initial P_2O_5 content of a sea water sample to which 2 cm.^{3} of 38 % sulphuric acid had been added was 11 mg. per cubic metre. After two weeks this figure rose to 28 mg./m.^{3} and after six weeks to 54 mg./m.^{3}. The determinations were made with 2 cm.^{3} of neutral ammonium molybdate instead of the usual acid reagent, so that the final concentration of acid and molybdate were as usual.

In sea water stored with the acid molybdate reagent (2 cm.^{3} to each 100 cm.^{3} of sample) to which the stannous chloride was added after a month to complete the reaction, the same increase in phosphate was observed.

Toluene is useless as a preservative for sea water samples, whilst phenol produces a yellowish colour when the molybdate reagent and stannous chloride are added.

When 1 cm.^{3} of a 1 % solution of pure sodium fluoride was added to 100 cm.^{3} of the sample, no change in phosphate could be detected. Experiments were made with and without this preservative directly and after adding 30 mg. P_2O_5/m.^{3}.

The results are shown in the following table in which the figures are mg. of P_2O_5/m.^{3}.

Analysed on	13. January	31 25. March	10. April	
Sea water alone	26.4	32	30	
Sea water + NaF	26.4	26	26.4	
	16. January	27. January		
Sea water alone	24.6	24		
Sea water + NaF	24.6	24.6		
	19. February	5. March	10. April	20. May
Sea water alone	24	27.6	30	32
Sea water + NaF	24	24	24	25
	1. June	23. July		
Sea water alone	10.9	4		
Sea water + NaF	10.9	10.4		
	1. June	23. July		
Sea water + 30 mg. P_2O_5/m.^{3}	40	18		
Sea water + 30 mg. P_2O_5/m.^{3} + NaF	40	40		

Thus sodium fluoride has been found to be an excellent preservative for sea water samples for phosphate determination.

A System of Rational Units for Reporting Nutrient Salts in Sea Water.

By

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IN a previous publication on nutrient salts [1]), the writer suggested that the present system of reporting nutrient salts as mg. P, P_2O_5 or PO_4'''; Si, SiO_2 or SiO_3''; or N, might with advantage be replaced by one based on the milligram-atom of P, Si or N. The unit of volume would remain the cubic metre. The proposal would simplify nutrient salt work in the same way that the use of the chemical equivalent enormously simplifies volumetric analysis. The atomic ratios, P:Si:N:N:N, are identical with the molecular ratios, H_3PO_4 (or $^1/_2\ P_2O_5$):H_2SiO_3:HNO_3:HNO_2:NH_3, or the ionic ratios, PO_4''':SiO_3'':NO_3':NO_2':NH_4', and can thus give a better idea of the relative consumption of the different nutrient salts by the plankton. The use of a multiplicity of units is to be deprecated owing to the difficulty which different workers encounter in appraising each others results, but since for phosphate and silicate three units (mg. P_2O_5, P, PO_4'''; SiO_2, Si, SiO_3'') are already in common use, the position would be clarified by the general adoption of the milligram-atom.

Independently, N. M. Carter, E. G. Moberg, T. Skogsberg and T. G. Thompson, representing laboratories on the Pacific Coast of North America, have prepared a manuscript on "The Reporting of Data in Oceanographical Chemistry" for presentation at the Fifth Pacific Science Congress which was held in June 1933 in

[1]) Chemical Constituents of Biological Importance in the English Channel, November, 1930, to January, 1932. Part I. Phosphate, silicate, nitrate, nitrite, ammonia. Journ. Mar. Biol. Assoc., N. S., XVIII, p. 714, (1933).

Table I.

Factors for Converting Conventional Units to Milligram-Atoms. In all cases the volume unit is the cubic metre.

To convert			Multiply by
mg. P_2O_5	to mg.-atom	P	0.0141
mg. P	„		0.0322
mg. PO_4'''	„		0.0105
mg. SiO_2	to mg.-atom	Si	0.0167
mg. Si	„		0.0356
mg. SiO_3''	„		0.0132
mg. N	to mg.-atom	N	0.0714
mg. Fe	to mg.-atom	Fe	0.0179
mg.-atom P	to mg.	P_2O_5	71.0
„	to mg.	P	31.0
„	to mg.	PO_4'''	95.0
mg.-atom Si	to mg.	SiO_2	60.1
„	to mg.	Si	28.1
„	to mg.	SiO_3''	76.1
mg.-atom N	to mg.	N	14.0

Table II.

In all cases the volume unit is the cubic metre.

0.500	mg.-atom P	=	35.5	mg.	P_2O_5
5.00	mg.-atom Si	=	303	mg.	SiO_2
7.00	mg.-atom N	=	98	mg.	nitrate-N
0.50	mg.-atom N	=	7.0	mg.	nitrite-N
2.00	mg.-atom N	=	28	mg.	ammonia-N
0.20	mg.-atom Fe	=	11.2	mg.	Fe
0.20	mg.-atom Cu	=	12.5	mg.	Cu
0.20	mg.-atom As	=	19.8	mg.	As

British Columbia. The writer is greatly indebted to Dr. Moberg for a copy of this manuscript and for permission to quote from it. It is there suggested that the milligram-atom should be used not only for nutrient salts but for all dissolved constituents of sea water. Furthermore, since a weight-weight relation is claimed to be more logical than a weight-volume, the litre or cubic metre could with advantage be replaced by the kilogram or metric ton for all purposes. They say, "The reporting of concentrations per liter or cubic metre is undesirable because the volume is a function of the temperature. Ordinarily the volume of a sample of sea water taken for analysis in the laboratory has a temperature of 20° C., but working conditions may vary and a lower or higher temperature may occur in the laboratories of different regions. Thus the values obtained on a volume basis are reported for conditions of a given laboratory and do not represent the situation *in situ*. These objections are eliminated if concentrations are reported as per kilogram or metric ton."

"The use of the expression milligram-atom per unit weight of water removes any confusion; it refers directly to the characteristic element of the compound determined; and it makes possible a logical interpretation of data ..."

Further, "It may be argued that the change is so small for many of the minor constituents that the conversion to quantities per metric ton is unnecessary, and while this may be true for certain elements, nevertheless, cases may be cited where the small change is of sufficient significance as to give a different interpretation of data ..."

In the opinion of the present writer, the metric ton is certainly logical but its use introduces complications such that many workers might prefer to make no change at all. For nutrient salt determinations the water is always measured by volume and the correction to a weight-weight basis although small will involve additional calculations every time. Again, as Dr. Atkins has pointed out to the writer, for calculation of plankton yields weight per unit volume is much the more conveneint. And to be completely logical the correction for salt error in phosphate determinations would also need to be made. To give some idea of the change involved in reporting as milligram-atoms per cubic metre Table I shows commonly used units converted to the milligram-atom. These apply whether the cubic metre or the metric ton is used.

In Table II quantities of minor constituents commonly encountered in sea water are converted from the conventional to the suggested unit. In the case of certain constituents, e. g., phosphate, fractional values are involved, a disadvantage which might be overcome by choosing a sub-multiple of the milligram-atom as unit. But this defect seems trivial when compared with the advantages which would arise from the general adoption of the milligram-atom as the unit for the minor constituents of sea water.

An important oceanographical quantity is the ratio, $\frac{\text{excess base}}{\text{chlorinity}}$,

termed by Wattenberg[1]) the "specific alkalinity", which is of value in determining small changes in calcium in the sea. The ratio considered has always been on a volume-weight basis, viz.,

$$\frac{\text{milliequivalents excess base per litre of water}}{\text{grams Cl per kilogram of water}},$$

to which the criticism of the American investigators applies with considerable force. Whether or not a weight-weight ratio is the more logical when small differences are being studied as by Wattenberg on the "Meteor" and by the writer in the English Channel is worthy of discussion.

For the dissolved gases also the American committee recommend the milligram-atom per cubic metre. They say that it is difficult to understand the logic of reporting constituents of sea water on a weight-volume or weight-weight basis and the dissolved gases on a volume-volume basis. This may be so, but the practical convenience of the millilitre of gas (reduced to 0° C. and 760 mm.) per litre of water is great owing to the application of the gas laws. The same advantages would, of course, follow from the use of the milli*mol* per litre or per kilogram but certain gases such as carbon dioxide cannot be expressed as milligram-atoms. Neither can excess base. On balance, reporting dissolved gases on a volume-volume basis, although perhaps not strictly logical, is very convenient and a change would seem to bring little advantage.

The considerations in this article are put forward tentatively for the attention of oceanographers.

Summary.

It is suggested that the most convenient unit for reporting minor constituents of sea water, including nutrient salts, would be the milligram-atom per cubic metre or, in line with the Pacific Coast investigators, the metric ton. This latter unit although more logical is less convenient. The major constituents might also be brought within the scheme using the litre or kilogram as measure of the sea water. The advisability of including dissolved gases and excess base is discussed.

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[1]) Über die Titrationsalkalinität und den Kalziumkarbonatgehalt des Meerwassers. Wissenschaftliche Ergebnisse der Deutschen Atlantischen Expedition auf dem Forschungs- und Vermessungsschiff "Meteor" 1925—1927, Band VIII, S. 141, (1933).

The Importance of Larval Mollusca in the Plankton.

By

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LITTLE was known about the biology of larval marine molluscs until quite recently, although a fair amount of scattered information may be found in the works of various authors, most of whom dealt with the eggs or newly hatched forms[1]). Their importance in the economy of the sea is very great. During the last few years the present writer has undertaken researches in the Plymouth Marine Laboratory with the object of investigating the planktonic molluscan larvae, the work so far dealing with the gastropods only. The results are astonishingly interesting, for not only have many elaborately formed and beautiful free-swimming larvae, hitherto unknown or undetermined, been identified with their adults, but many of them are found to occur in such numbers that they must influence considerably the general life of the plankton. They may do this in two ways.

(1) They are wholly planktonic feeders and, in the veliger stage, with every movement they are taking into their bodies the nanno-plankton, chiefly diatoms, but also other minute organisms both animal and vegetable, thus competing to a large extent with the other plankton feeders.

[1]) References to these works are not given. The sign × after a name indicates that the observation is new but still unpublished, O indicating that the observation is not new but has been confirmed by the present writer. The dates after species refer to the present writer's works, a list of which may be found at the end of the paper.

The nomenclature followed is that of Mr. R. Winckworth's new list of British Marine Mollusca (Journal of Conchology, Vol. 19, No. 7, 1932.) If different from that used in the revised Plymouth Marine Fauna 1931 (Marine Biological Association) the equivalent names are inserted in brackets.

(2) They are themselves food for many planktonic animals and in some cases are so important in this way that they may form the chief food of our plankton-eating fishes (Herring, Pilchard and Sprat) especially in their young stages. At certain times of their lives many invertebrates also feed on them, thus indirectly helping in food chains, the green plant being eaten by the larval mollusc, the mollusc by some invertebrate which is itself eaten by a fish and the fish eaten by man.

Both bivalves and univalves usually have free-swimming larvae which are members of the plankton for a short or long period (from a few hours to probably several months) although this is not universally the case and in gastropods some species are viviparous and others hatch out in the crawling stage, in both cases a veliger stage being observed within the egg.

In most lamellibranchs there is a short free-swimming stage, the eggs being sent out in clouds into the sea, there to be fertilised and develop quickly into veligers with a simple round velum: the British oyster, however, keeps the young in its gills until both velum and shell are well developed and the young swim away from this shelter soon to settle down as spat. The primitive gastropods *(Archaeogastropoda)* mostly have a similar simple velum. Patella (O) and its relatives send out their eggs into the sea and these hatch as small shell-less veligers, the shell forming in a few hours. Some of the *Trochidae* do the same. This is the case in the species of *Gibbula* whose eggs are known *(G. magus, G. cineraria)* but *Cantharidus*[1]) and *Calliostoma* lay their eggs in gelatinous masses or ribbons. *Cantharidus striatus* and *C. exasperatus* attach these masses to some substratum, in *Calliostoma papillosum* they float. *Calliostoma ziziphinum* (O) lays gelatinous chains on the glass sides of the aquarium. In *Cantharidus* and *Calliostoma* the larvae are hatched without a velum, having passed the veliger stage within the egg.

In the *Mesogastropoda* the velum is bilobed, and multilobed in some of the later stages of the larger veligers. In the *Lacunidae* (including *Littorina)* we have several very common littoral gastropods, some of which live above the region of ordinary spring tides and are only watered by the spray. Typical of this region is the common *Littorina saxatilis (= rudis)* (O) which is well known to be viviparous in all its many varieties. *Littorina littoralis* (O) and *Lacuna* (O) deposit their eggs on *Fucus* in small gelatinous masses, the former hatching in the crawling stage, the various species of the latter, which may also be found beyond the low water limit, hatching out as veligers with a fairly large bilobed velum and remaining in the plankton for some time. *Littorina littorea* (O) the common periwinkle, living between tide-marks and just below the low water limit has planktonic egg-capsules shaped like the British infantryman's shrapnel helmet and containing usually two to five eggs. The young hatch

[1]) In the Plymouth Marine Fauna the genus *Cantharidus* is by an error spelt *Cantharus* (p. 254).

out as veligers with a conspicuous bilobed velum having dark purple marks on each lobe, the larvae remaining in the plankton for some time (×). In the *Hydrobiidae (= Assimineidae)* which prefer estuarine waters, *Hydrobia jenkensi* is viviparous and *H. ulvae* (O), living on mud, lays its lens-shaped egg-capsules on the shells of its companions, the larva hatching out as a free-swimming veliger with a bilobed velum. Most of the *Rissoidae* so far known have lens-shaped egg-capsules laid on weed, hydroid or bryozoon, containing several eggs, but *Rissoa sarsii* (×), which is being investigated at the present moment, has minute planktonic egg-capsules, each containing one egg, the free-swimming larva coming from it serving as an important food for the newly-hatched Herring (see below, page 000). *Cingula (Cingula) semistriata* (×) has the typical rissoid capsules with several eggs but *Cingula (Onoba) semicostata* (×) lays its eggs singly in a thick oval capsule, the young emerging without any velum. *Rissoa parva* (O),and *R. membranacea* (O) have typical rissoid egg-capsules but whereas only a few larvae hatch from the capsules of *R. membranacea* (×), some of them devouring the others ("nurse eggs"), in those of *R. parva* (×) and *R. guerini* (×) and also *Cingula semistriata* the complete number of eggs develop. In all a bilobed veliger results, usually (except in *R. membranacea,* whose larva is large and soon crawls) remaining for some time in the plankton. All these are littoral forms living between tide-marks or near low water. In the *Tornidae, Tornus subcarinatus* (×) has a beautiful little bilobed veliger and much ornamented shell, remaining for some time in the plankton, the adult living on the rocks between tide-marks, and in the *Skeneopsidae, Skeneopsis planorbis* (O) lives in rock pools high up, the young having no free veliger stage.

In the *Turritellidae, Turritella communis* (1933 d), abundant locally on mud from about 15 to 40 fathoms, lays its eggs in grapelike masses of capsules, each capsule containing several eggs which hatch as veligers with a bilobed velum, the larva only remaining in the plankton for a short time. In the *Cœcidae,* the larvae of two species of *Cœcum* are to be found in the coastal plankton, swimming about with a planorbis-shaped shell and bilobed velum (×).

The adult, living either in the shallow water or rather further out, loses the whole of this coiled shell and remains sausage-shaped with the tip filled in by a shelly plate. The *Cerithiopsidae* are mainly associated with sponges, *Cerithiopsis tubercularis* (1933 c) usually living in the crevices of *Hymeniacidon sanguinea* or, more rarely, *Halichondria,* on which it lays its eggs, and *C. barleei* (1933 c) living in or on *Ficulina ficus,* biting holes in it and laying eggs in the holes. Both species hatch out as bilobed veligers remaining in the plankton until they have several whorls. The closely related *Triphora perversa* (1933 c) also has a bilobed velum and a long larval stage. These three species may occur as larvae in the plankton from the coastal waters to far out over a depth of 30 to 40 fathoms. In the *Eulimidae* the species of *Eulima* have several whorls before settling down, the larva

with a bilobed velum. The eggs of *Eulima polita* (×) are laid in oval, opaque, white capsules on some substratum and contain many eggs. The closely related *Pelseneeria stylifera* (= *Stylifer stilifer*) (1932 b) lives on echinoids, laying its eggs in triangular bags on the test, the larvae emerging as veligers with a bilobed velum. In the *Pyramidellidae,* all of which have sinistral embryonic shells but are dextral animals, those whose eggs are known lay them in small capsules on some substratum, the young hatching with a bilobed velum and metamorphosing when the shell becomes dextral and not staying long in the plankton. Those whose eggs have been seen are *Chrysallida (Parthenia) decussata (= Pyrgulina decussata)* (×), *Odostomia (Brachystomia) eulimoides* (1933 b), living on *Chlamys opercularis* and laying its eggs there, and *Turbonilla (Tragula) fenestrata (= Tragula fenestrata)* (×). In the *Calyptraeidae, Calyptraea chinensis* (O) covers its eggs, which are in triangular capsules, with its shell until the young emerge in the crawling stage having lost the velum, the adult living in shallow water beyond the low tide level. In the *Aporrhaidae, Aporrhais pespelicani* (1933 d) living in shallow or deeper water deposits its eggs singly in shell gravel, the larva emerging as a veliger with a bilobed velum soon changing to four and then to six lobes, each lobe having a mass of almost black pigment at the end. The larva of *Aporrhais* remains for a long time in the plankton and reaches a large size (1.25 mm.) before metamorphosis. In the *Naticidae, Natica (Lunatia) catena* (O) and *N. (Lunatia) poliana (= N. alderi)* (O) form spirals or semi-spirals of agglutinated sand with the eggs in capsules embedded in them. Both species live in sandy gravel, *N. catena* having "nurse eggs" but not *N. poliana* (O). Both have brown pigment on the velum which at first is bilobed in both species, one of them (probably *N. catena)* having four long lobes later. Both larvae remain for some time in the plankton.

Next come the *Lamellariidae* including *Velutina* and *Lamellaria,* and the *Cypraeidae* including *Erato, Trivia* and *Simnia.* There seems to be a close relation between the larvae of *Lamellaria* and *Velutina* on the one hand and *Erato* and *Trivia* on the other, *Simnia* being quite different and more like the true Cypraeas. *Lamellaria perspicua* (O) is well known for making its nests in compound ascidians, the larvae hatching out with a beautiful little nautiloid *Echinospira* shell, this *Echinospira* surrounding the true shell and serving as a float. The larva hatches with a bilobed, but slightly indented, velum, the later stages having six lobes. An allied form from deeper water at Plymouth also has six lobes. These *Echinospira* larva remain for a long time in the plankton. *Velutina* (×) has a gelatinous covering over the true shell, serving the same purpose and occupying the same position as the *Echinospira* of *Lamellaria* but without perceptible whorls. *Trivia* bites holes in compound ascidians and deposits its eggs in these enveloped in their vase-shaped capsules, the lips of which protrude. The two species *Trivia monacha* (1931 c, 1933 a) and *Trivia arctica* (1933 a) have *Echinospira* shells slightly different from those of *Lamellaria,* the

late veligers differing in the shape of the velum, that of *T. monacha* being only slightly indented at the sides, of *T. arctica* being four lobed. *Erato voluta (= laevis)* (1933 b) has a helicoid *Echinospira* shell with a velum similar to that of *T. monacha.* All these which have an accessory float in the form of an *Echinospira* shell or gelatinous covering are so specially modified that they may stay some time in the plankton and reach a large size *(Lamellaria* 2 mm., *Erato* 2 mm., *Trivia* 1.25, 1.6 mm.). *Simnia patula* (1932 a) which lives and feeds on the soft corals *Eunicella* and *Alcyonium* lays its eggs in a layer of capsules on these, the young hatching with a dark brown reticulated shell and colourless bilobed velum, the velum later growing out into four long lobes and the larvae staying for a long time in the plankton.

Coming now to the *Stenoglossa,* many of these lay vase-shaped capsules attached to some substratum and in several cases the young are hatched in the crawling stage having passed the veliger stage within the egg. Here we have *Trophonopsis muricatus* (O) with lens-shaped capsules containing very few eggs, the young crawling when newly hatched, *Nucella lapillus* (O) with vase-shaped capsules laid on the rocks, most of the eggs being devoured within the capsules by the few which hatch out in the crawling stage, *Ocinebra erinacea* (O) with angular vase-shaped capsules, *Buccinum undatum* (O) with its large masses of capsules containing many eggs most of which are devoured within the capsule. Most of the other species of the Buccinidae known hatch in the crawling stage. In the *Nassariidae, Nassarius reticulatus* (1931 a) and *N. incrassatus* (1931 a) both lay flattened flask-shaped egg-capsules attached to weed, bryozoon or hydroid, all the eggs hatching and the veligers remaining for a long time in the plankton. *N. reticulatus* has the velum bilobed and but slightly indented in the later stages, but in the older veliger *N. incrassatus* has four long lobes each with brown pigment at the end and this larva extends much further out to sea than *N. reticulatus.* In all the *Turridae* known, lens-shaped capsules are laid on some substratum. The Philbertias have beautifully sculptured larval shells, *P. leufroyi* (×) and *P. linearis* (×) with colourless four-lobed velum, *P. (Comarmondia) gracilis* (1933 c) with four long lobes decorated with orange and brown spots, *Mangelia nebula* with an enormous velum covering the shell like a real veil. All these have horny shells, which attain a large size before settling down, and remain for a long time in the plankton *(P. gracilis* = 1.76 mm.).

Besides all these planktonic forms mentioned above there are innumerable larval Opisthobranchs (including the *Pleurocoela, Pteropoda* (1931 c, 1932 c) and *Ascoglossa)* most of which are free-swimming for part or the whole *(Pteropoda)* of their life. If we add to these all the larval lamellibranchs we have a host of molluscs in the plankton which must be of enormous importance in the sea.

The coastal waters differ slightly from the more open waters (15—40 fathoms) in the kind of larvae present in the plankton,

although in many cases there is overlapping. In the shallow-water plankton near the coast are the larvae of *Patella*, the *Trochidae*, *Littorinidae*, most of the *Rissoidae*, *Cæcum*, *Tornus*, many of the *Pyramidellidae*, the two species of *Nassarius*, the two species of *Trivia*, some turrids, *Cerithiopsis*, *Triphora*, *Lamellaria*, *Aporrhais*, and *Eulima*. The first three are almost confined to the shallower waters but all the others may be found further out. In the deeper waters, however, we find the larvae of *Trivia arctica* and not *T. monacha*, *Philbertia leufroyi* and not *P. linearis*, *Nassarius incrassatus* and not *N. reticulatus*, *Erato*, *Simnia*, and the second species of *Lamellaria*.

The velum of the larval mollusc is large or small according to the length of time the larvae stay in the plankton, those with the largest shells usually possessing the most elaborate velum (*Aporrhais*, *Philbertia gracilis*, *Trivia*, *Lamellaria*, *Erato*, *Nassarius*, *Mangelia nebula* etc.). The velum is a powerful swimming organ and is bordered at the edge by a groove having an upper layer of long cilia and an under layer of shorter cilia, the groove leading to the mouth on the ventral surface in front of the foot in the early stages, the foot usually growing beyond it later. These cilia constantly moving create a current in the groove which continually wafts food, nannoplankton, into the mouth. This food consists chiefly of diatoms and minute flagellates, but dinoflagellates and even tintinnids (*Infusoria*) have been observed inside the larger veligers and also such diatoms as *Thalassiosira*, *Skeletonema* and *Lauderia* — even the needle-shaped *Rhizosolenia* and stiff chains of *Paralia* are sometimes taken.

In the plunger jars where the mollusc larvae were reared (either from the egg or from the planktonic larva) a pure culture of *Nitzschia closterium* was given and on this diatom together with others which appeared in the water *Nassarius reticulatus* was reared from the egg to the crawling stage, the process taking two months. The chief forms found inside these larvae in the plunger jar were *Nitzschia closterium*, *Thalassiosira gravida* and *Skeletonema costatum* the two last often still in chains in the stomach. In the same species from the plankton *Thalassiosira* and *Skeletonema* were very frequently found. In smaller veligers very small diatoms and small green cells were seen (probably flagellates). *Nitzschia closterium* is too large for the smallest forms which in the plunger jar appear to feed on some much smaller unidentifiable organisms, the stomach usually being full of greenish substance.

In one specimen of a late larva of *Nassarius reticulatus* from the plankton, the following food was identified:—

Thalassiosira gravida many, some in chains, some separate.
Skeletonema costatum many.
Paralia sulcata one
parts of *Rhizosolenia* sp.
Tintinnopsis heroidea 2.

The natural position of the larva when swimming in the plankton is with the shell below and the foot and velum above, but the velum, especially when long lobes are present, may alter its position in many ways, the lobes flapping slowly, completely covering the shell or remaining outspread. As the cilia move the whole time, the food is being wafted into the mouth continually and there is no cessation of feeding. It is clear that mollusc veligers must compete with other planktonic feeders to an enormous extent.

An interesting case well illustrates the above remarks. Recent work on Norwegian oysters (Gaarder and Spärck 1933) has shown that the veligers of a species of *Cerithium* is a very important competitor for food with the oyster larvae, hatching at the same time and feeding on the same nannoplankton. The *Cerithium* larvae are in some years many times more numerous than the oyster larvae themselves. If we know the habits of the molluscs which compete for food with those of commercial importance we shall be near the solution of many problems. It has been shown above (page 337) that two species of *Cerithiopsis* (a genus closely related to *Cerithium)* are always found associated with certain sponges and these sponges are probably necessary to them. If a similar association were to be found in the oyster pools we may find a means of ridding them of the competing larvae. Apart from the need of knowing all that is to be known of the biology, including the life history, of all those molluscs which are of commercial importance, it is also necessary to know all we can about their molluscan neighbours which, although neither useful nor harmful from the point of view of human consumption, yet indirectly may be of extreme economic significance.

The breeding season or seasons of each species of mollusc should be carefully ascertained and here there is a wide difference in the various species. Even in winter there are several veligers which are abundant in the plankton. Confining our remarks to the gastropods studied we have *Patella vulgata, Littorina littorea, Trivia arctica, Nassarius incrassatus, Lamellaria perspicua* and various members of the *Rissoidae* all spawning in winter, although some of these may continue into the spring or even breed throughout the year. Most of the molluscs, however, breed in spring and summer and after the spring diatom maximum a large influx of veligers is to be seen, continuing throughout the summer and well into the autumn. *Patella vulgata* has practically finished spawning in March, *Littorina littorea* in May, although a few may continue through the summer. *Trivia arctica* gives place to *Trivia monacha*, the latter breeding from late spring throughout the summer, *Nassarius incrassatus* continues through spring and early summer and its larvae are common with those of *N. reticulatus* in spring and summer, the late larvae of *N. incrassatus* usually being a feature of the plankton in late spring and summer. *Lamellaria perspicua* breeds throughout the year but especially in spring and summer. Others beginning in early spring are *Aporrhais, Lacuna, Cerithiopsis, Triphora, Odostomia* and its relatives, many rissoids and

turrids. Many of these continue throughout the summer. *Trivia monacha, Simnia patula, Erato voluta* are almost wholly late spring and summer breeders. Enough has been cited to show that some kind of gastropod veliger is always in the plankton and the various seasons have also their opisthobranchs and lamellibranchs.

The breeding of certain species coinciding with the hatching of others which eat them may be of great significance and this brings us to the second, and perhaps the more weighty, reason for stressing the economic importance of molluscan larvae in the plankton: *they may form the food of commercially important animals.* It is specially the young fishes which illustrate this. To take but one instance, that of the clupeoids; at the whitebait stage the young of herrings, pilchards and sprats occur in enormous numbers round our coasts and have frequently been found to be full of larval lamellibranchs, probably oysters, cockles or mussels. A still more interesting case is now being investigated. The newly hatched herrings from the mouths of the estuaries and just off the coast very frequently are found to contain larval gastropods at the stage when the veliger is just out of the egg. Even when there are remains of the yolk sac still in evidence the baby herring eats this mollusc. In 1921 it was found that out of 140 of these very young herrings examined 91 contained these larval gastropods (L e b o u r 1921).

This little mollusc has proved to be *Rissoa sarsii,* which is not one of the commonest shore forms. It has been found to hatch from a minute floating egg-capsule, common in the plankton, only 0.16 mm. across, the newly hatched veliger measuring 0.054 mm. across the shell. When still inside the capsule and when newly hatched the shell is marked in a peculiar and characteristic manner with longitudinal striations and small dots in between, and these markings are clearly seen on the shell inside the baby herring. Just at the time the herrings hatch in the coastal waters an enormous number of these veligers also hatch out (December to February). They are some of the commonest if not *the* commonest molluscs in the coastal plankton at that time and occur together with the larvae of other rissoids, *Patella vulgata* and *Littorina littorea.* It was, however, noted that although the baby herrings sometimes contained very young lamellibranchs of about the same size as the gastropod in question, no other gastropod larvae were found inside them, those of *Patella* and *Littorina* probably being too large.

The older larva has been reared in a plunger jar until recognisable as *Rissoa sarsii.* The veliger remains for some time in the plankton, the shell attaining 2½ to 3 whorls when it can either crawl or swim. In this stage the apex of about 1½ whorls is clearly seen to be marked with the characteristic striations and dots. If the adult could be collected in numbers it might be possible to give the baby herrings hatched in the Laboratory that early food which is most natural to them.

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Further Experiments on the Selective Action of Commercial Drift Nets.

By

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IT is a feature of a herring community, or, indeed, any other fish population, that there are always more young fish in the stock than there are old ones. The number of eggs which are deposited by the females during the spawning season, and the number of larvae which swim about after the spawning are impossible to estimate, and a single haul with a small seine net on the shore in the summer months will yield a supply of yearling herrings which, three or four years later, would represent a catch of several crans, but the decrease in the stock, caused by both natural mortality and the action of the fish's enemies, including man, is so great that by the time the herrings are six years old, their numbers are insignificant in comparison with their original strength.

Fortunately, however, the early existence of the herring — with the exception of a comparatively small whitebait fishery — is more or less immune from the attacks of man, for, as is now well-known, there is a definite line of demarcation between those fish which submit themselves to the ravages of the drift net, and those young fish which never appear in the catches. The controlling factor which governs the shoaling of these fish seems to be maturity, and very briefly, the history of the early movements of the herring of the southern North Sea can be outlined as follows: during the first year of its life, the young fish seeks the shallow waters of the coast and the larger estuaries, where it remains until it is approximately one year old. The second year is spent in the open waters of the North Sea, where large numbers of these fish can be caught, using suitable gear, around the slopes of the Dogger Bank and in other areas to the south of the Bank. Here the fish feed and build up supplies of fat, until, in their third year they begin to show signs of sexual development. It is not until then that the coastal migration begins, when the fish move to the rough places of the sea bottom which they appear to prefer as spawning grounds. It is clear, therefore, that the herring community is divided automatically into two separate stocks, the maturing and the immature

fish, and since it is the former part of the division which is fished commercially, it follows that the trade is concerned only with fish which are older than three years.

The catchable stock of the east coast is again further divided according to age, the fishery from the Northumberland coast to Cromer Knoll being composed mainly of three and four-year old fish, and the East Anglian fishery of three to ten or eleven-year old fish.

We have, thus, a stock of herrings of different ages and sizes along our coast which should be sufficiently great to supply all the needs of the industry at the present time, and it is the object of this paper to show how this stock should best be exploited if we are to reap the fullest benefit from it.

A preliminary note on the selective action of drift nets was first published in Vol. II, No. 3 of the Journal du Conseil in 1927, and therein it was demonstrated that the selectivity of these nets was much 'sharper' than had hitherto been supposed. Since that time, observations of a tentative nature have been made, especially at North Shields, using a fleet of mixed drift nets from the motor vessel "Onaway", and, according to the nature of the nets used, it has been conclusively shown that (a) the quality (i.e., size) of the herrings caught is absolutely dependent on the size of the mesh used, and (b) it has been possible to catch very large herrings and mackerel in a fishery which is normally supposed to yield only the smallest of herrings. Large sprats, too, have been caught in this same area.

In 1932, it was decided to carry out an experiment on a commercial basis, and this was done at North Shields and Lowestoft, from drifters while they were carrying on with their normal work. At North Shields, a fish-measurer sailed for several voyages, and after measuring the size of mesh of the various nets used, he collected the herrings which were caught in these different nets and measured them.

At Lowestoft, the procedure was somewhat different. Nine new nets were purchased in the following sizes: three each of 31, 33, and 35 rows per yard, and these were placed in the middle of the fleet of the drifter "Boy Alan" (Skipper S a g o). Observations were made in both October and November, and a measurer accompanied the vessel on each series of experiments. His duty was to measure the herrings which were taken by each series of meshes, and also the herrings which were caught by the ordinary nets of the drifter.

Here are the results of the measurements.

North Shields.

The observations for the period 12th to 20th July 1932 have been added together according to the size of the mesh used, and in the following table are to be found the total length composition of the drifter's catch, and also the length composition of the fish taken from each individual net.

Table 1.

cm.	Total catch	33 rows	36 rows	38/40 rows	42 rows
16	0.2			0.2	
17	0.1				
18	4.4		0.4	6.9	10.4
19	25.0	5.3	5.5	32.0	45.8
20	28.8	15.8	18.6	34.0	31.3
21	21.5	28.9	23.6	17.5	8.3
22	10.4	18.4	22.4	6.7	2.1
23	4.4	13.2	15.6	2.2	2.1
24	2.7	15.8	8.9	0.4	
25	1.3	2.6	3.4		
26	1.0		1.3		
27	0.2		0.4		
28	0.1				
29				0.2	
No. of fish measured	1202	38	237	538	48

(The figures in the table represent percentages).

In Figure 1 these measurements are shown graphically.

The curve which represents the total catch of the drifter has a peak or 'mode' at 19.7 cm. which means that this size of herring was the commonest which was caught. The 42 and 38/40 row nets both caught herrings which were slightly smaller than this size, the 42 row mesh producing a peak at a position about 0.25 cm. below that of the 38/40 net.

There is a marked difference between these nets and the 36 and 33 row meshes. The former of these caught fish whose commonest size was about 21.5 cm., with a trace of larger ones about 24 cm. in length, and the 33 row net was clearly catching two well-marked groups, one 21.25 cm. and the other 24 cm. in length.

In terms of age, it can be said that the total catch, and the fish taken by the 42 and 38/40 row nets were mainly *small* three-year old herrings, while the other two nets were taking the larger three-year olds plus a few fours and fives. Figure 1 thus gives a clear demonstration of how the character of the landings can be varied according to the size of mesh used.

Lowestoft.

The stock of herrings which makes the East Anglian fishery so productive is, as has already been explained, quite different from that of the north-east coast. Here it is the exception to have large quantities of three-year old fish, and four and five-year old herrings are the most abundant, taking the season as a whole. Also, unlike the fishery further north, there is a period, towards the end of the season, when fish of seven, eight or even nine years of age predominate, thus under conditions such as these, where the range of length is great, it is to

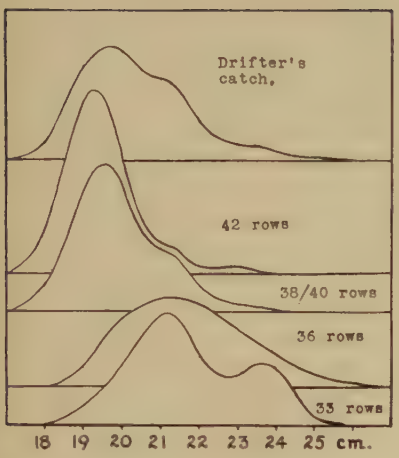

Fig. 1. Showing the difference in size of herrings according to the mesh used at North Shields.

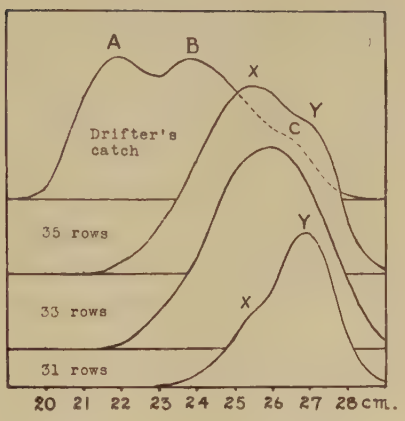

Fig. 2. Mesh experiment — October 1932.

be expected that the effect of mesh will be stronger than in a fishery where the length range is restricted.

In Table 2 are the measurements of the drifter's catch and of the fish from each of the special nets which were placed in the middle of the drifter's commercial fleet, when she was fishing in the neighbourhood of Smith's Knoll between the 25th and 27th of October 1932.

Table 2.

cm.	Total catch	35 rows	33 rows	31 rows
20	1.2			
21	13.8	0.3		
22	19.0	1.7		
23	16.6	6.6	5.1	0.4
24	18.6	15.2	12.3	3.6
25	14.8	23.9	23.7	13.7
26	9.4	24.4	26.9	25.3
27	5.4	20.4	21.9	41.5
28	0.6	6.9	9.0	13.4
29	0.4	0.6	1.2	1.4
30				0.7
No. of fish measured	499	348	334	277

(The figures in the above table are percentages).

In Figure 2, these observations are drawn in the form of frequency curves after the method described by Wollaston and Hodgson in the Journal du Conseil Vol. IV, No. 2, 1929.

In the first curve it will be seen that there are two well-marked groups which have been distinguished by the letters A and B. There is also a trace of a third group at C. Now, the commonest sizes of the herrings which make up these groups are, for the first, 21.8 cm., for the second, 24 cm., and for the third, about 26.5 cm., and these lengths, we know from the scale examinations, correspond to ages of three, four and five, and about eight.

The three lower curves represent the lengths of the fish caught by the three nets with meshes of 35, 33, and 31 rows per yard respectively, and at a glance, one sees that the smallest group A in the curve for the total catch of the drifter, is missing from all three. Instead, these nets have concentrated on the larger fish, group C, which in the drifter's catch was but poorly shown. The 35 rows per yard net caught two groups of fish which we can call X and Y, and which are composed of fish aged about six and eight years. The group X is slightly better represented than group Y. In the case of the next net, 33 rows per yard, a broader curve is produced and the peak of this one is about midway between the two groups shown in the previous net. This suggests that this net has caught the groups X and Y in more or less equal proportions. Next, the curve of the 31 rows per yard net shows these two groups in still different proportions. This time it is the group Y which is more abundant, and the other is only present in small numbers.

The November experiment was carried out with the same drifter working in approximately the same area, between the 16th and 19th of the month, and the measurements are shown below in Table 3.

Table 3.

cm.	Total catch	35 rows	33 rows	31 rows
20	0.1			
21	4.5	0.4	0.5	0.2
22	12.9	1.5	1.5	1.4
23	10.9	4.3	5.0	1.6
24	21.8	23.4	19.1	7.8
25	20.1	27.3	22.7	18.1
26	15.4	20.6	22.3	24.3
27	11.7	17.6	19.8	30.0
28	2.4	4.3	8.6	14.4
29	0.1	0.6	0.5	2.3
No. of fish measured	792	671	660	514

(The figures in the table are percentages).

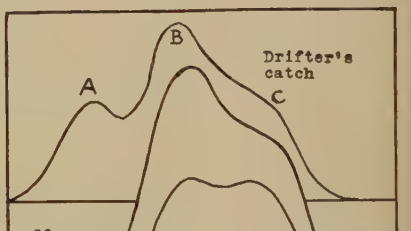

Fig. 3. Mesh experiment — Nov. 1932.

These measurements are shown graphically above in Figure 3. As before, the three groups A, B, and C are again shown in the curve for the total catch of the drifter, and the positions of the modes are at approximately the same places as in Figure 2.

Again the effect of our special nets has been to cut off the smaller group of three-year old fish entirely, but, probably owing to the group B being more abundant in the shoals than it was in October, it remains in evidence in the catches of the three nets.

The same changes in the composition of the catches according to the size of mesh used are again shown. The 35 row net caught more of B than of C, the 33 row net caught the two groups in almost equal proportions, and the 31 row net caught more of C than of B.

It is clear from these two experiments that there is a very definite and subtle gradation in the length of the herrings caught by nets of even slightly different meshes, and it is also plain that the whole character of a fishery can be changed by the use of different nets.

The reason why these experiments have been carried out is two-fold. First, it was desirable to know to what extent the size of mesh affected the landings of herrings, and, secondly, they were made necessary by a number of complaints from the industry as a whole regarding the alarming increase of "small matties" in the cure.

The history of the change in the mesh used on our east coast is difficult to trace, but it is definite that since the war there has been a tendency on the part of skippers and owners to use nets of smaller mesh than they did in the years before the war.

There are two possible reasons for the change. It may have been brought about by the extra expense of maintenance of the nets so that owners have been forced to use their gear for longer periods than they did formerly, or it may have started with the discovery by some skipper that if he used small-meshed nets in certain areas he would get very much increased catches. Such a discovery, especially when herrings were in demand soon after the war, would soon prove to be very popular, and in time it would become the recognised custom to fit smaller meshed nets. Whatever be the original cause of the change, it is established on the evidence of net manufacturers that the present demand is for new nets of smaller mesh than those used before the war, and this, in addition to the fact that the nets are used for longer periods than before, is quickly leading up to a situation which in former times would have been regarded by the trade with astonishment.

How great is the difference between the pre-war nets and those commonly in use today? It has been possible to get some idea of the change by enquiring from the factories, and from old experiments carried out by the Ministry (formerly the Board) of Agriculture and Fisheries in 1913. In that year, an investigation into the effect, if any, of herring trawling on the drift industry was reported on, and in the course of the work it was necessary to examine the catches of drifters at both North Shields and Lowestoft and the sizes of mesh used are given in the report on the subject (Fishery Investigations: Ser. II, Vol. IV, No. 4).

Therein it is stated that "the drift nets used in the east coast herring fishery, show a small variation in mesh, there being from 30 to 36

'rows' or meshes to the yard .... The finer meshed nets are used principally in the earlier part of the season, and therefore from the more northerly ports, such as North Shields. From August onwards it appears that the great majority of the drift nets employed all down the coast from North Shields to Lowestoft have 31—32 rows to the yard." From a net manufacturer there is documentary evidence that the size of the majority of the nets made from 1911 to 1914 was 30 to 31 rows per yard, and that in recent years most of the new nets which have been ordered have been 32½—33 rows per yard, and these are used first in the Scottish fishery and not until they have shrunk considerably are they used in the East Anglian fishery. It is difficult to get actual figures regarding the size of mesh used at Lowestoft and Yarmouth today, but from conversations with skippers and owners it seems that the average size is about 37 rows per yard.

Let us now compare the catches of herrings on the east coast in 1913 with those of 1932.

At North Shields, we have a series of measurements of fish taken between July 12th and August 19th 1932. These are shown below in Table 4.

Table 4.

cm.	July 12/20	July 20/28	July 28-Aug. 6	Aug. 8/13	Aug. 15/19
18	4.4	1.4	0.4	0.1	0.2
19	25.0	14.4	7.2	3.4	2.4
20	28.8	26.6	18.3	11.3	11.1
21	21.5	25.5	22.0	14.5	16.9
22	10.4	20.5	25.2	20.9	20.7
23	4.4	6.2	12.8	19.3	18.9
24	2.7	2.9	7.4	16.3	16.4
25	1.3	1.3	3.8	8.5	8.1
26	1.0	0.9	1.9	4.1	3.7
27	0.2	0.2	0.4	1.4	1.2
28	0.1		0.4	0.2	0.3
29		0.1	0.1	0.1	
No. of fish measured	1202	1276	1545	1323	1157

(The above figures are percentages).

These measurements are shown in Figure 4 as frequency-curves.

It can be seen that during the period between July 12th and August 19th the character of the fishery is gradually changing. The commonest size caught at the beginning of this period, as represented by the mode of the first curve, was 19.75 cm. and this mode moves its position to the right until in the last sample it appears at 22.25 cm. There are two possible causes of this change. First, it must be remembered that in July the herrings are growing fairly rapidly, and added to this we know that at this time there is an immigration of older fish to the grounds.

Similar variations to this are shown in the report on the 1913 investigations. It was then found that from the first half of June to the first half of August there was a steady increase in the size of the

herrings, the median value varying in a continuous manner from 23.47 cm. to 24.84 cm. (The *median* can be defined as a line drawn at right angles to the base line of the curve, and which divides the curve into two equal areas.)

If we compare the positions of these median values which mark the change that took place in the fishery in 1913, with the medians of the frequency curves for 1932 (see Fig. 4) it will be sufficient, without the aid of mathematical treatment, to demonstrate the great difference between the two fisheries. The 1932 landings are the result of the use of nets with 38 to 42 rows per yard meshes and the 1913 landings of nets whose meshes were from 31 to 36 rows per yard.

At Lowestoft and Yarmouth, we find that in 1913 the following sizes of fish were caught, using nets of 30 to 33 rows per yard.

Table 5.

cm.	2nd half Oct.	1st half Nov.
22	2	1
23	7	8
24	27	20
25	29	31
26	19	21
27	9	11
28	5	5
29	2	2
30		1
No. of fish measured	11,096	7,789

(These figures are percentages).

In the following Figure 5 these lengths are compared with the measurements made during the corresponding period in 1932, but it must be remembered that the season 1913 was an extraordinary one, for in that year there were the largest landings ever recorded, due, we believe, to an abnormally rich stock of four and five-year old fish. It is this abundance of young herrings which makes the older fish in the curves look insignificant. In 1932, however, there was also an abundance of five-year old herrings, as well as many fours, so these two seasons are quite comparable.

The difference between these two sets of curves needs little explanation. Not only are the 1913 modes somewhat higher than those of 1932, but there is also a complete absence of the small group with a mode at about 22 cm., which has become a regular feature of the East Anglian fishery in recent years. The pre-war catches, then, were very similar to those which were made with the special nets in the experiment described in Figures 2 and 3, inasmuch as they contained none of the herrings which were shown to be three years old.

Certain curers have intimated that before the war they had never cured a "small mattie", while now they were finding an increasing

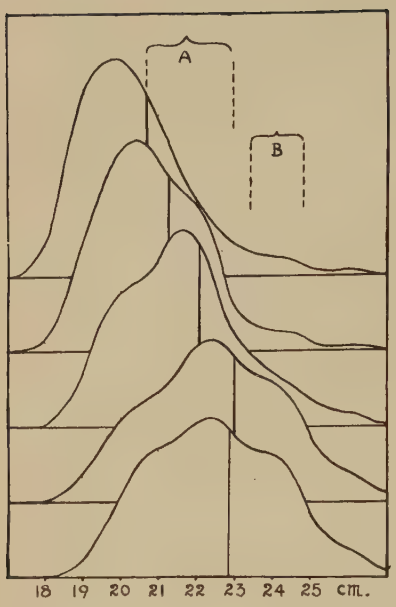

Fig. 4. Showing the changes in the herring shoals at North Shields between July 12th and August 19th 1932. 'A' is the median range for this period, and 'B' the median range between June and August 1913.

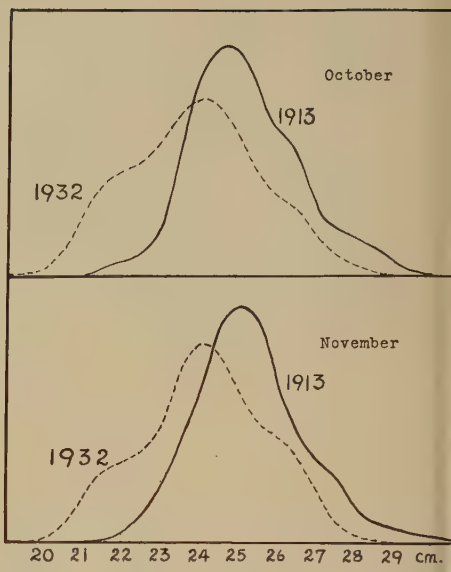

Fig. 5. The size of the East Anglia herrings as landed by gear use in 1913 and in 1932.

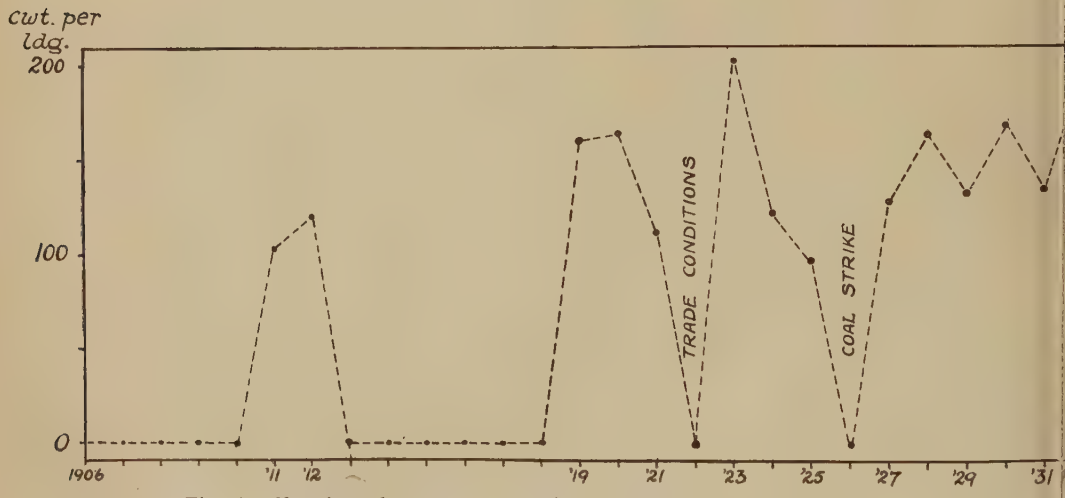

Fig. 6. Showing the average weight per landing of herrings at Yarmouth and Lowestoft for the month of September from 1906 to 1932.

quantity of these small fish. The explanation would appear to be that formerly in the East Anglian fishery none was landed, and even at North Shields, which was recognised as a small fish area, the smallest meshed nets in use at that time would exclude a very large proportion of these small herrings. (Fig 1).

The Effect of Small Meshed Nets on the Stock.

At the beginning of this paper it was described how the composition of our stock was naturally defined, and how our main fisheries depended on herrings which were between the ages of three and about ten years, but, while the range of the ages in the stock may remain constant, there is a possibility of a considerable variation in the proportion of the ages of the fish taken from the stock. We know, roughly, the limits of the stock with regard to age, and it should be the aim of the industry to use this stock in such a manner as to get the best possible results from it. It is axiomatic that there are always more young fish in the sea than there are old ones, so, if quantity, regardless of "quality", is the aim of the industry, it is only necessary to use very small meshed nets to attain this object. But what of the future?

Constant observation of the changes in the age composition of the chief fisheries has shown that the herrings which appear in any one year in the shoals will, provided that they are not caught, reappear the following year. A large number of five-year old fish will produce a large number of six-year olds and so forth, so it is obvious that any big onslaught on a group of young herrings will have an effect which will be transmitted through the whole life cycle of that particular year-class. We also know that a year-class reaches its maximum abundance at about four or five years of age, and that after that time it begins to decrease in numbers until at eleven years of age only a vestige remains in the shoals. During this time between maximum abundance and total disappearance, the herring is growing in size, from about 9½ inches to about 11 inches, that is, through the grades known to curers as "matties" to "fulls".

The effect, therefore, of catching large quantities of three-year old fish must be to cut down the supplies of these larger fish in later years, and the continuance of the practice must lead to a change in the composition of the stock, by making an addition to the already considerable rate of decrease. It will tend to cultivate a stock consisting almost entirely of the younger herrings, and in time it will be useless to fish for the larger ones, because there will not be a sufficiently large supply to make the fishery profitable.

That something like this is happening at the present time is shown by the amount of herrings caught in the various nets during the experiments carried out at Lowestoft. The average catch per net in quarter-cran baskets was as follows:

35 rows	33 rows	31 rows
5.6	3.0	0.6 baskets

Thus the 31 row mesh, which was catching eight-year old fish of 10¾ inches in length, would have produced only about one-ninth of the catch of the 35 row meshes, which were taking four, five, and six-year old herrings.

Further evidence of the enormous attacks on the three-year old stock is furnished by the diagram in Figure 6.

This figure represents the average catch per landing at Yarmouth and Lowestoft for the month of September in the years 1906 to 1932. Before the war, with the exception of the years 1911 and 1912, there were no landings in this month, but after 1918 the landings have been fairly high. In 1922 and 1926 there were no landings because, in the first case, the economic situation interfered with fishing and, in the second, no supplies of coal were available owing to the strike. The reason for the fishing in September since the war is probably the decline in importance of the Grimsby fishery in that month, and consequently the drifters are making an earlier start on the East Anglian grounds than they did formerly, although some of the landings are of fish taken on the Dowsing ground.

During this early period, we have seen that the greater part of the herrings landed are three and four-year old; thus an extended fishing in the early part of the season, especially with small-meshed nets, is yet another factor which is *sure* to increase the landings of small matties, and at the same time is calculated to deplete the stock.

The magnitude of the landings by *weight* for October and November has not altered much since 1906, but, considering actual *numbers* of fish, it must be remembered that the small-meshed nets are taking a much greater toll than did the nets in use before the war.

In view of an increasing amount of foreign competition, it should be the aim, therefore, to improve the quality of the herring on our east coast, rather than to destroy it, and there is no doubt that this could be achieved by a return to the pre-war standard of net. The protection of the three-year old fish would mean the end of the real "small mattie" in East Anglia and a considerable reduction of those seven and eight-inch fish which are landed at North Shields in the summer, but it would also mean an increased catch in later years of matties, mat-fulls and fulls, and, further, a limit in the size of mesh used would enable a vastly increased number of fish to spawn and so help to augment the stock, for, coming as they do into the shoals for the first time at three years of age, the herrings are ripening for the first time, and as they are caught in this maturing condition, these fish are never allowed to spawn once under the existing conditions.

Any change in the mesh of drift nets must of necessity be gradual, owing to the financial condition of the industry, but it could easily be brought about by replacing old nets by new ones of the pre-war standard, and, finally, as there is a difficulty at present of getting rid of the supplies of herrings which are landed, the decreased catches which would result from the use of larger nets should not be a serious deterrent.

The Number of Vertebrae in *Gadus virens* L. from the Norwegian Skagerak Coast.

By

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ON examining the number of vertebrae in some samples of young coalfish (*G. virens*) of the year-group 1932 from these waters we have obtained certain results which are so interesting that I thought it desirable to give a preliminary report.

As shown by the late Professor Johs. Schmidt (1930) the number of vertebrae differs from one cod population to another; further, he suggests that the temperature of the water is the chief cause of the variation, high temperatures giving few vertebrae, low temperatures many. His investigations show, moreover, that the number of vertebrae diminishes as we pass from the coast into the fjords.

District	Date	Length cm.	Number examined	Number of Vertebrae in: Fjord	Skjærgaard
Kragerø					
Kilsfjord	29/9. 32.	15.0 — 18.5	96	53.40	
Risør					
Søndeledfjord ..	27/9. 32.	14.5 — 19.0	105	53.43	
Sandnesfjord ..	30/9. 32.	13.5 — 17.5	88	53.42	
Arendal					
Håvekil	26-27/6. 32.	6.5 — 12.0	175		53.58
Stølsvik	17/2. 33.	17.0 — 23.0	1035		53.49
Lillesand					
Homborsund ..	28/6. 32.	5.5 — 11.5	122		53.63
Aset	—	4.5 — 12.0	442		53.59
Lusekilen[1])	29/6. 32.	6.5 — 11.5	125	53.58	
Brekkestø	—	7.0 — 13.0	1350		53.57
Kristiansand					
Topdalsfjord ..	29-30/9. 32.	7.0 — 11.7	1240	53.56	
The Naze					
Korshavn	1/7. 32.	7.5 — 11.0	157		53.68

[1]) A small fjord only 2 nautical miles from the coast.

Our preliminary examination of the coalfish shows that the last conclusion probably holds good for this species as well. The number of vertebrae is smallest in the fjords and higher near the ocean. It increases also as we pass along the Skagerak coast from the NE. to the SW. The table shows the average number of vertebrae (the urostyle is not counted). The material will be dealt with statistically later.

In large samples the material was divided into three groups: Small, medium and large. The number of vertebrae is as follows; the figures in brackets indicate the number of fish examined.

Locality	Small	Medium	Large
Stølsvik	53.42 (274)	53.51 (468)	53.54 (293)
Aset	53.55 (173)	53.64 (131)	53.61 (138)
Brekkestø	53.51 (479)	53.57 (500)	53.65 (371)
Topdalsfjord	53.47 (455)	53.58 (371)	53.64 (414)

It is evident that there is a great difference in the number of vertebrae between the smallest and the largest fishes of the year-group. When dealing with the number of vertebrae from this species at least, it is therefore essential *that the sample represent the different sizes of a year-group in the normal proportions.*

The relation between the length of the fish and the number of vertebrae is also of interest in another way. Is the number of vertebrae a feature connected with the growth or the size of the fish?

The following considerations are apropos to this question.

a) We know that larvae hatched from small eggs are smaller than those from larger eggs of the same species.

b) The smaller specimens of a batch will tend to remain behind the rest in growing up.

c) Finally, from the examination of the coalfish we know that small specimens have few vertebrae.

In this way small eggs may produce specimens with few vertebrae, and large eggs many vertebrae. This explanation is, however, not in opposition to the opinion of Professor Schmidt, Mr. Bjerkan and others regarding the effect of temperature on the number of vertebrae. We must remember that the size of the pelagic eggs of our common spring-spawning fishes diminishes as the season advances, i. e., we find the largest eggs early in the season when the water is cold. It is therefore possible that the sea temperature has something to do with the size of the eggs and thus indirectly with the number of vertebrae, but the temperature itself is apparently not the factor immediately actuating.

In the case of the coalfish the spawning season is very short, and the spawning regions so limited that it is hardly reasonable to suppose that any essential temperature differences are experienced by the individuals occurring in the same shoal a few months after hatching. We must seek other causes also — one of which may be the size of the eggs.

Notes on the Optical Appearance of Winter Rings in some Clupeoid Scales.

By

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ANYONE who has a working acquaintance with the scales of the herring or sprat is familiar with the apparent transparency of the winter rings in contrast with the more opaque appearance of the broad zones of growth. Rather surprisingly, no adequate and generally accepted explanation of this optical effect seems to have been given in the principal works on the scales of Clupeoids. For instance, S a v a g e (1919) states that "no importance is attached in this report to any theory that the clear edge indicates the beginning of the formation of a transparent winter ring, because in the first place, the apparent transparency of a winter ring has not been explained, and in the second place, it is by no means certain that the striations play any part in causing its appearance."

L e e (1920) finds that in the herring scale "the striae are generally present in these (the winter) rings. Perhaps they are less strongly marked, but they appear as well to alter or bend in their course as they pass over the winter ring. The general effect produced is that of a clear, transparent narrow zone". D a h l (1907) considers that the greater transparency of the winter ring is caused to some extent by irregularity and faintness of the striations. P a g e t (1920) finds that it is the "comparatively smooth, unbroken surface of the ridge of the upper layer (found by him in sections of the scales of *Cl. reevesi)* which is the real cause of the transparency of the growth rings in surface view." On this ridge the striae were ill developed. L e a (1919) does not specifically mention or explain this transparency, but, by means of taking casts of the upper surface of the scale, he has shown that the general aspect of the herring scale is entirely due to its superficial sculpturing and not to the optical peculiarities of its internal structure.

While engaged in examining sprat scales for the purpose of age estimation I was struck by the relative transparency of the winter ring and by the fact that this transparency was apparent, although the

striae were for the most part continuous and unbroken where they crossed the ring. I had also noticed, independently of Lee and doubtless in common with many other observers, the marked bending or temporary alteration in direction of the striae as they crossed the winter ring, and I became convinced that this bending or kinking was one of the principal causes of the transparency and consequent

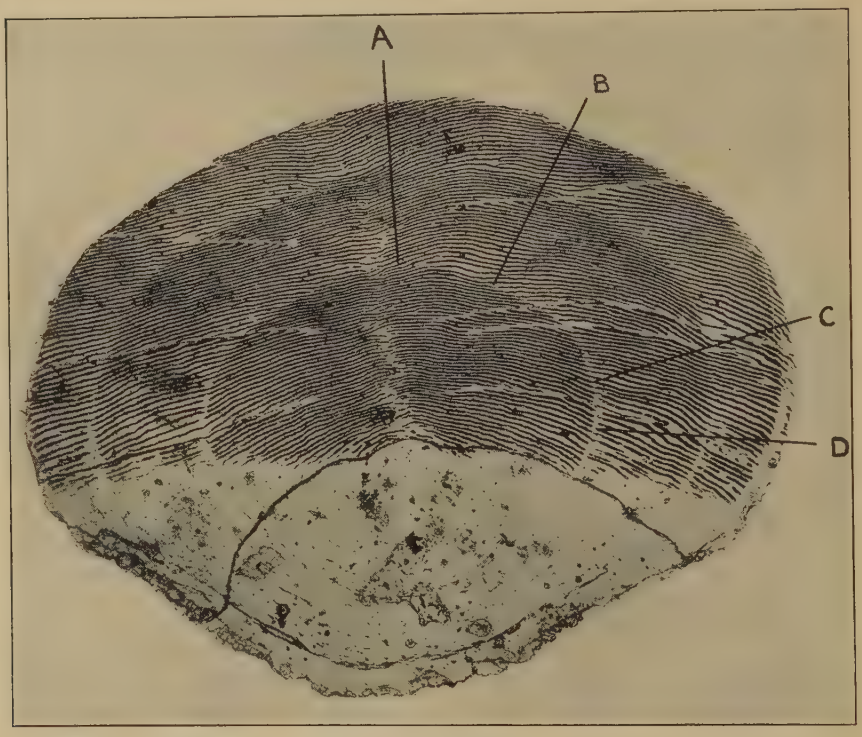


Fig. 1. Sprat scale. A. Apex, B. Shoulder, C. Side, D. Base of Ring. Photo. H. Stokes.

clearness of the ring. In the sprat scale, which is perhaps rather more coarsely striated than is usual in the herring scale, this bending is particularly noticeable in some cases, especially in scales with coarse striation (i. e., with wide spaces between the striae — for there seems to be some variation in the coarseness or fineness of striation in scales from different fish). The bending is usually most obvious on the shoulder of the scale (B, Figure 1), where the striae cross the winter ring at an acute angle as they follow their somewhat curved course across the surface of the scale. Closer to the base line (C, Figure 1), where the striae cross the ring approximately at right angles, the bending is less marked, while close to the base line (D, Figure 1),

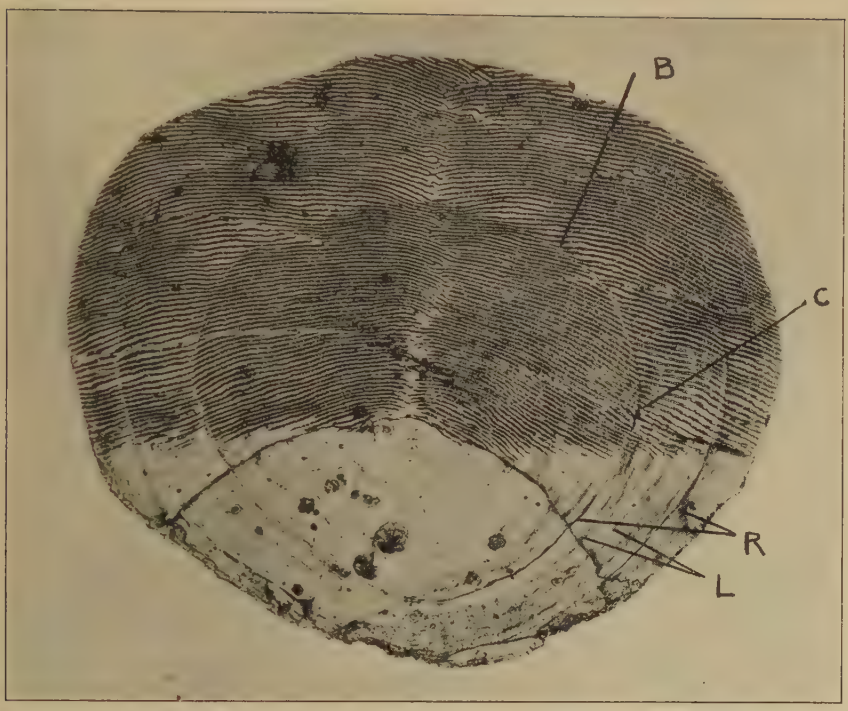


Fig. 2 a. Sprat scale. R. Edge-like lines, L. Edges of laminae (?). Photo. H. Stokes.

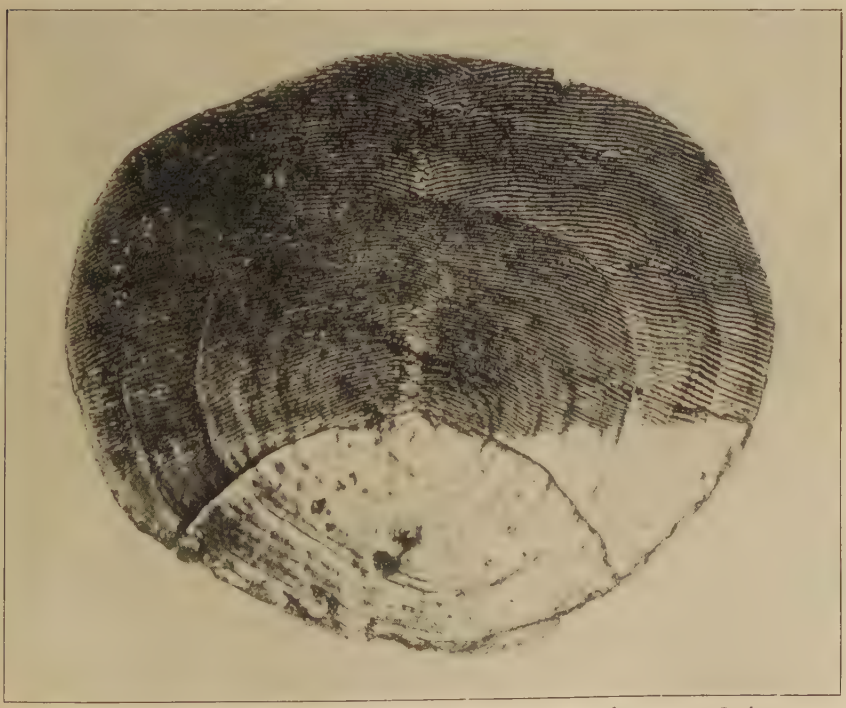


Fig. 2 b. Same scale under oblique illumination. Photo. H. Stokes.

and for a very variable distance from it, the striae tend to be interrupted and broken in the neighbourhood of the ring. At the anterior apex of the winter ring (A, Figure 1) the striae are tangential to it and there is little observable alteration in their course.

The whole picture is strongly reminiscent of the appearance, due to perspective, of furrows crossing a fold in a ploughed field.

Fig. 3. Herring scale; showing undulating edge-like lines on exposed portion. Photo. H. Stokes.

By the use of polarized light Savage (1919) has shown that the laminae, of which the lower layer of the scale is made up, project one below the other for varying distances. The wide projections formed in early summer are succeeded by progressively narrower projecting rims in late summer and autumn. Apparently the lower layer of the scale ceases growth altogether in winter, and, when with the following summer the formation of widely projecting laminae

is resumed, it can be seen that the region of sudden transition from narrow to broad laminar projections coincides with the position of the winter ring on the upper striated layer of the scale. This formation of the lower layer would naturally tend to involve an alteration in the general slope of the scale from the centre to the periphery, provided that the laminae are of *approximately* equal thickness[1]). The result would be that the scale, usually described as a flattened cone when viewed in section, would have an upper layer with a slightly variable slope. These variations in slope having the character of terraces or low cliffs, might, by slight distortion such as a further flattening of the cone, become ridges possibly accompanied by an external *fossa*, representing the top and bottom of such a distorted cliff.

On the posterior exposed surface of a sprat scale one or two marked concentric edge-like lines, continuous with the winter rings of the striated portion, are usually plainly visible (R, Figure 2a) in addition to less distinct lines (L) which may represent the edges of laminae. In the herring scale these edge-like lines appear to have an undulating outline (Figure 3), but this is not the case in sprat scales I have examined. These lines have every appearance of being just such low cliffs or ridges as have been suggested above. The resemblance is particularly apparent under the binocular microscope and with oblique lighting (Figures 2b and 4a). I am of the opinion that they are sometimes ridges and sometimes cliffs, for under oblique illumination on a projector they throw shadows or reflect light from their surfaces in accordance with the direction from which they are lit up. In the case of supposed ridges they display both a bright face and a dark face (in shadow) when lit up from either one side or the other (compare R_1 and R_2 in Figures 4a and 4b), whereas in the case of a supposed cliff illuminated from one side or the other a bright face alone, or a shadow only, is visible. Where a ridge occurs it seems likely that its outer face will be deeper than its inner face in view of the general slope of the surface of the scale.

In a section of the scale (Figure 6) these irregularities in slope are far from distinct; indeed even the rigde-like striae and base line of the striated portion, although very prominent in surface view, are much less clearly defined when seen in section, in which they appear as small protuberances on the surface of the upper layer. It is, therefore, not surprising that the cliffs or ridges, which are vaguer and less noticeable than the striae in surface view, should be even less readily distinguishable in section. In this connection it may be remarked that the exposed projecting edges of the laminae forming the lower layer may be seen fairly distinctly in surface view, but in section are invisible owing to the overlying upper layer of the scale.

The width of the exposed portion of the scale is less than that of the anterior striated portion, and for this reason the slope of the

[1]) Savage states that the laminae, when viewed in section, appear to "fan out" at their edges. Provided this fanning out is more or less uniform, my hypothesis is not invalidated.

Fig. 4 a. Sprat scale illuminated from right side. Photo. H. Stokes.

former, from base line to periphery, is more abrupt than that of the latter. The irregularities in the slope are therefore emphasised more strongly on the steeper exposed portion and are visible as slight cliff-like undulations on the upper surface of the section (cf. arrows in Figures 6 and 7), whereas they are only doubtfully distinguishable on the anterior portion, possibly owing to the masking effect of the protuberances formed by the striae. In surface view, however, the cliffs or ridges visible on the exposed portion of the scale can be traced into the striated portion for varying distances from the base line. This is most readily seen under the binocular microscope or with slightly oblique illumination (Figures 2a and b and 4a and b). In the apical region of the winter ring these ridges are usually indistinguishable. The indistinctness of these cliffs or ridges in the anterior portion, in surface view as in section, is probably due in large measure to the close sculpturing of the striae, which tends to obscure underlying irregularities of the scale surface.

There seems to be little doubt that the scale is in fact a very much

Fig. 4 b. Same scale illuminated from left side. R1 and R2: (primary) ridges in striated portion reflecting light and casting shadow. L: secondary ridges; probably unusually prominent edges of laminae. Photo. H. Stokes.

flattened cone and that the edge-like lines seen upon the exposed portion, which coincide and are continuous with the winter rings of the striated part, are actually irregularities in the general slope of the upper surface. It is evident that the edge-like lines are not merely an optical illusion resulting from peculiarities in the inner structure of the scale, for I find that they, like the striae and other surface features, are apparent in celloidin impressions of sprat and herring scales made according to L e a's method (1919) (Figures 8a and 8b). Close observation of the bends displayed by the striae as they cross the winter ring gives a very strong impression that the striae pass down over a low terrace, or up and over a ridge and down its outer slope. Any series of parallel lines passing over a terrace edge which lies at an angle *(other than a right angle)* to their course, appear to bend sideways owing to perspective[1]), and conversely the optical effect

[1]) I am unable to find a more suitable term for this effect. It should not be forgotten that perspective may be curvilinear as well as rectilinear, and is the method of representing a three dimensional object on a two dimensional surface.

of the bends in the striae gives the impression of a cliff or ridge, quite apart from any consideration of the lines resembling terrace edges seen upon the non-striated portion of the scale.

Consideration of Figure 1 will help in explaining the apparent transparency of the winter ring. As has been remarked, the striae bend but little at A where they meet the winter ring or cliff tangentially. At B, however, the striae meet the cliff edge at an acute angle and in consequence of perspective they appear to bend slightly as they pass over it. In this part of the scale each stria passes over the cliff edge or ridge a little beyond its neighbour and, as a result,

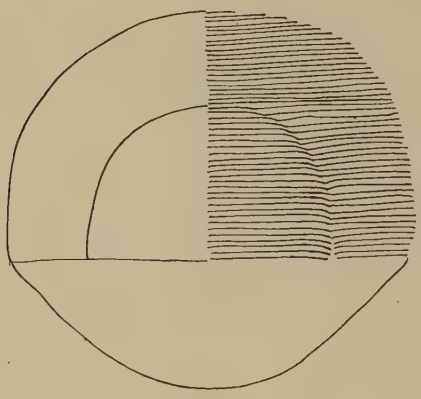


Fig. 5 a. Diagram to illustrate curvature of striae passing over a cliff or ridge. Photo. H. Stokes.

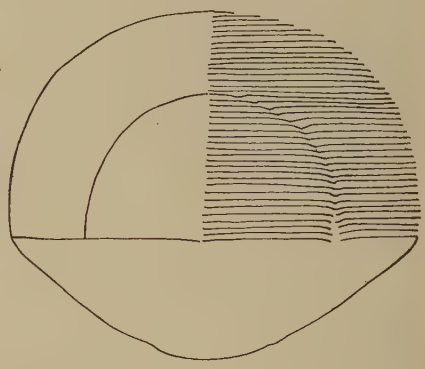
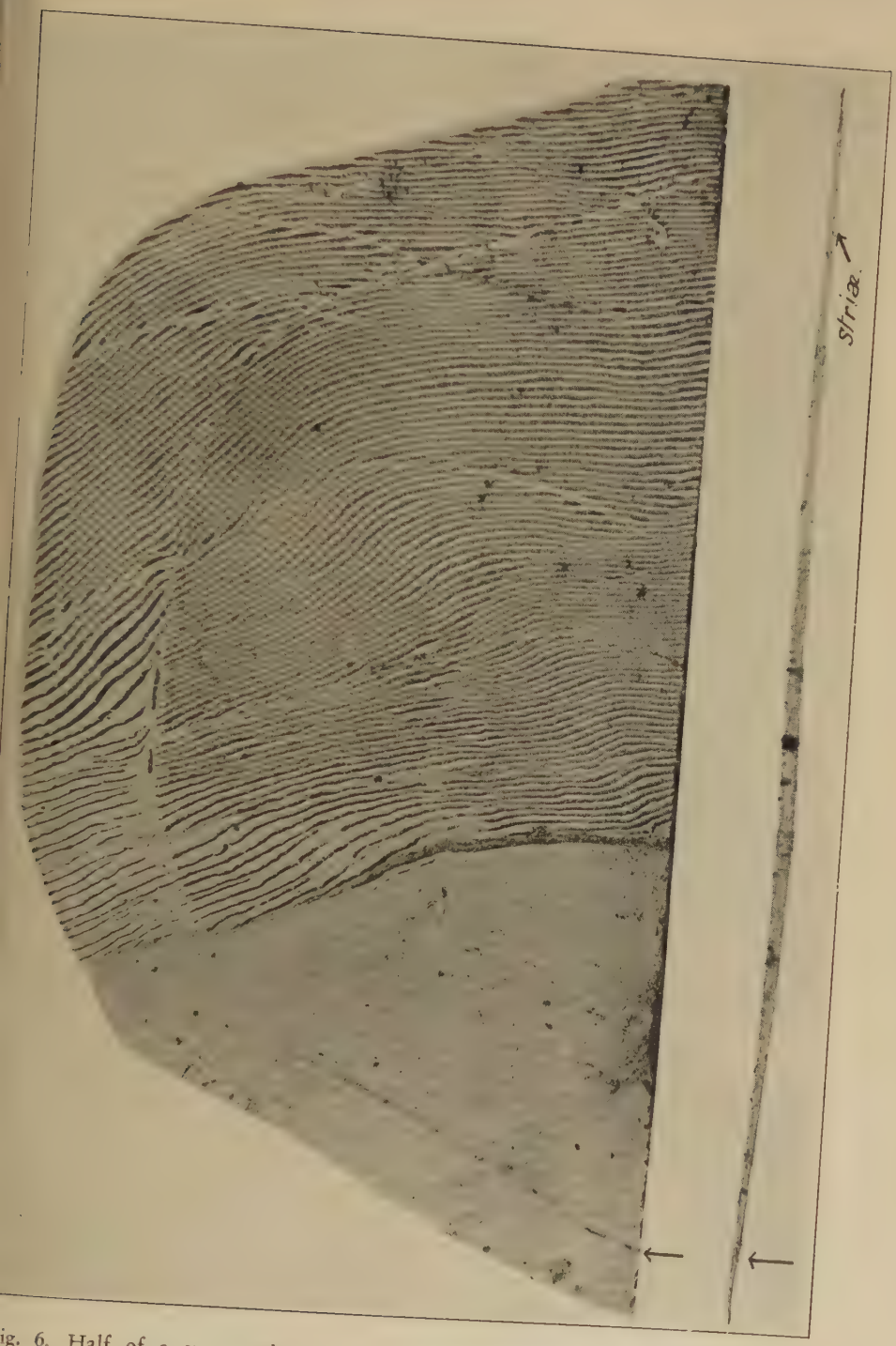


Fig. 5 b. Diagram to illustrate curvature of striae passing over a groove. Photo. H. Stokes.

the bends do not occur one almost directly below the other as they do at C, where the striae meet the winter ring approximately at right angles. This results (at B, Figures 1 and 2a) in each stria, as it dips down in passing over the cliff or ridge, apparently bending so that it approaches its neighbour which has not yet met the cliff edge, and diverging once more when it has reached the bottom. Many successive striae apparently approximate and diverge again in this manner where they meet the winter ring at an acute angle (B, Figures 1 and 2a), thus producing the appearance of a relatively dark border where the approximations occur, and, outside it, the effect of a lighter band where the striae once more separate. This is particularly apparent if Figure 1 is examined with half-closed eyes and is no doubt an effect of the distribution of dark lines (striae) and pale inter-strial areas. Contrast is produced when an area in which striae are crowded together abuts upon one in which they are widely separated, in a manner similar to that used in producing light and shade effects in a pen-and-ink drawing. The effect produced by the lighter band of diverging striae outside the darker area of approximated striae is



ig. 6. Half of a sprat scale and a section of the same scale (× 48). Arrows dicate edge-like line on scale and corresponding declivity in section. Striae on upper (external) surface of scale. Photo. H. Stokes.

that of a relatively transparent ring, which effect the eye tends to carry round to C, where the bends in the striae occur one above the other and no convergence or divergence of the striae can arise in this manner. At D the incompleteness of the striae further emphasises the transparency at the winter ring. Another factor which seems to contribute to the transparency of the winter ring, particularly in some

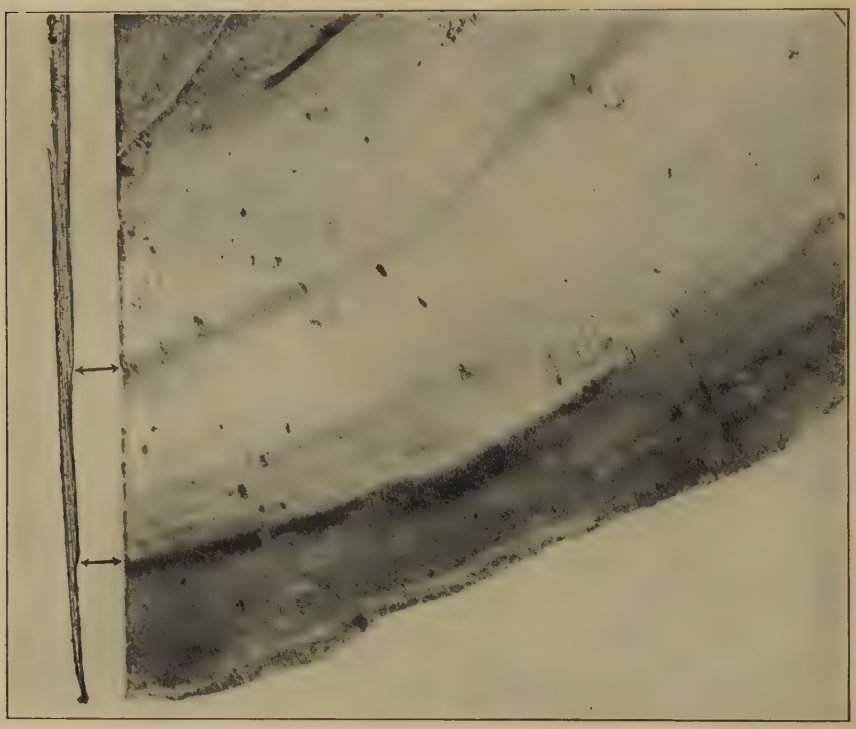


Fig. 7. Part of the exposed portion of a sprat scale and corresponding section of the same scale (× 120). Arrows indicate edge-like lines on scale and corresponding declivities in section. Margin of the scale at the bottom of the figure. (Exceptionally clear specimen). Photo. H. Stokes.

scales (Figure 2a), is that the striae just outside a winter ring appear to be actually further apart than they are inside it, *to remain wide apart* for some distance and to converge again as they approach the periphery of the scale. This widening occurs both at B and at C and seems to be independent of the relative positions of the successive bends in the striae. It seems possible that this protracted widening and subsequent convergence is merely a specialised variation of the phenomenon of deposition of widely spaced striae in the early summer and of more crowded striae later in the season, such as is found in the concentrically striated scales of salmon and sea-trout and also in the concentrically striated scales from behind the dorsal fin of the herring (cf. Paget 1920, p. 18).

Lateral scales from the sprat and herring are of course crossed by transverse striae which curve only very gently towards the base line and pass from one growth-zone into the next. New striae are only added anteriorly and those which are laid down first sometimes appear to be more widely spaced than those which are formed subsequently (Figures 1 and 2a).

There seems to be little doubt that the transparency of the winter ring is in part attributable to the effects of contrast brought about by variations in the spaces between the striae. These variations may result from perspective where striae pass over a fold on the scale surface, or they may be due to the actual widening of the inter-strial areas outside a winter ring. This latter disposition of the striae is far more obvious in some scales than in others. Finally, the cliffs or ridges, when illuminated from certain directions, reflect a line of light which runs across the striae, and contributes to the appearance of transparency (compare R_1R_2 in Figures 4a and b).

Figure 5a shows that a surprisingly realistic diagram, drawn upon very simple principles, may be made of the winter ring in a scale. In figure 5a a semicircle was drawn in pencil to represent the cliff or ridge (winter ring) and ink lines were drawn across it to represent striae, bending tangentially in a curve where they crossed the pencilled line. The right half of the pencilled semicircle has subsequently been erased, and, if inspected with half-closed eyes, this figure shows how simply and clearly the effect of a winter ring can be obtained.

Figure 5b shows that if, as is sometimes apparent on the scales, the lines are drawn as though they passed over a groove rather than over the edge of a cliff the transparent effect of the ring is even more striking. It may be remarked that quite a small degree of distortion will produce a ridge, or a groove, or a *vallum* and *fossa* from a simple cliff on a gently sloping surface such as that of a scale, and it is not at all impossible that sometimes one and sometimes another of these types of irregularity is present.

The distinctness of the bends made by the striae at the winter ring is very variable in different scales and is usually most marked in those scales in which the winter rings are clearly shown. From the foregoing account it is probable that the two are inter-connected.

The character of the ridges or cliffs on the scale surface and the behaviour of striae as they pass over any irregularity in the slope may help, in some instances, to explain the origin of false or secondary rings. For instance, the marked primary edge-like lines or cliffs seen on the exposed part of the scale sometimes seem to be doubled, or to bifurcate as they enter the striated portion. In many cases the less distinct secondary lines, which are visible on the exposed portion and which may merely represent the edges of laminae, are variable in development and sometimes appear as quite prominent ridges, but usually for a short distance only (L, Figures 4a and b). It is sometimes difficult to distinguish them from the primary edge-like lines and their effect upon the striae seems to be similar, if perhaps less

pronounced and confined to a restricted area. Quite frequently ridges or cliffs may be seen upon the exposed portion which do not appear to affect the anterior portion and leave the direction of the striae undisturbed. This is often the case in the very centre of the scale and the edge-like line may here represent the margin of the original scale-plate.

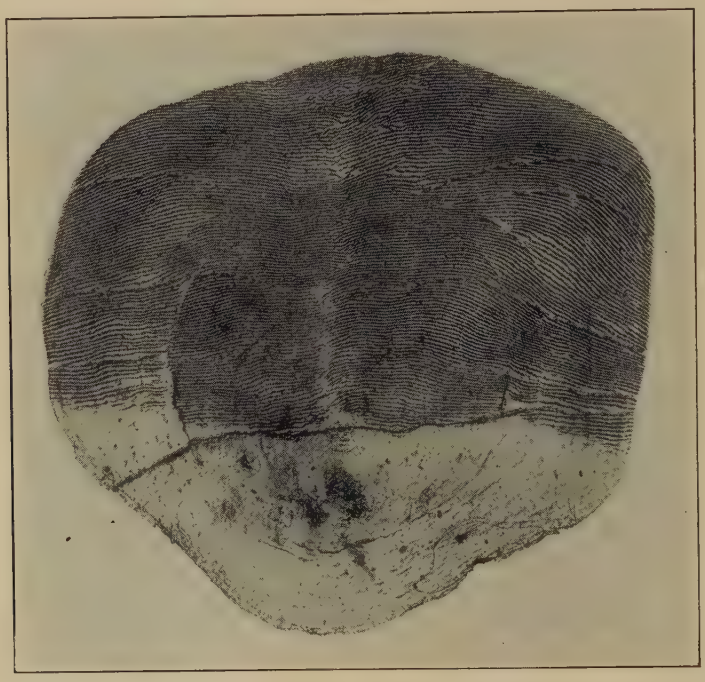


Fig. 8 a. Sprat scale (× 18). Photo. H. Stokes.

It is possible that exceptionally prominent secondary ridges or cliffs are the result of a reduction in the width of the projecting laminae of the lower layer, resembling the reduction which takes place in autumn, but in this case the consequence of a diminution in general growth which is due to other causes.

The fundamental cause of such false rings is, however, still obscure and it cannot be claimed that a criterion distinguishing false from true winter rings has been established along these lines. In so far as the transparent rings may depend upon the interaction of striae with ridges or cliff-like edges, and the latter upon the seasonal laminar make-up of the lower layer, we have some explanation of the seasonal occurrence of transparent rings in winter. It has also been remarked that the actual distances between striae in the apical region of the scale appear to vary seasonally.

While most of the account given above refers to the scale of the sprat, the same general features are observable in the herring scale[1]), and Figure 3 shows how the striae bend in passing over the winter ring, which is continuous with the cliff-like undulating edge upon the exposed portion. As in the sprat scale the bending of the striae seems to be responsible for the apparent transparency of the ring.

Fig. 8 b. Celloidin impression of same scale (× 18) forming a mirror-image of the scale. (N.B. The right side of the impression is out of focus owing to curling of the celloidin film.) Photo. H. Stokes.

Summary.

Attention is directed to the peculiar bending of the striae which occurs at the winter ring in the scales of sprat and herring. The probability of this being due to an effect of perspective, consequent on the striae passing over an irregularity or alteration in the slope of the scale surface, is considered. It is suggested that the transparency of the winter ring is an effect of chiaroscuro dependent on a difference in the spacing of the striae in adjacent areas of the scale. This difference in spacing may be due to perspective in the region of cliffs or ridges such as are seen upon the exposed part of the scale, or it

[1]) A curious difference is observable in "bad" (presumably regenerated) scales of herring and sprat. In the former the central disturbed area is filled with an irregular whorl of striae, while in the latter all striae are absent.

may result from a real seasonal variation in the distances between the striae such as is found in concentrically striated scales, or it may arise from a combination of both causes.

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Tagging Experiments on the Pacific Herring, *Clupea pallasii.*

By

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Introduction.

As previous reports have shown (Rounsefell, 1930; Rounsefell and Dahlgren, 1932), the Pacific herring is divided into a number of racial stocks or populations. The study of the causes of the fluctuations in the supply is greatly complicated thereby, especially in south-eastern Alaska (Rounsefell, 1931), where the fishery extends over a wide territory. In this district regulations intended to stabilize production and to prevent an undue intensity of fishing from falling upon any one stock of herring cannot be framed to the best advantage without more exact knowledge concerning the areas inhabited by each population during the year. The acquisition of such knowledge by biometrical methods entails the collection and analysis of tremendous masses of data. Further, the results of such a study are not as accurate or as detailed as those obtained by the release and subsequent recovery of marked fishes. Because tagging permits the formation of a more accurate estimate of the areal distribution of these populations, the following experiments were undertaken to determine whether or not a tagging program would be feasible.

The literature is almost devoid of allusions to the marking of herring. From the many places in which their delicateness is mentioned it would appear that they have long been regarded by most investigators as not being fit subjects for marking.

However, T. Wemyss Fulton (1893) of the Scottish Fishery Board marked a number of herring in 1892 at Ballantrae Bank by punching triangular holes in their tails. He found that unless the hole was very small the tissue broke between the hole and the margin of the fin. On account of this difficulty he abandoned the method. He made a second attempt in December, 1893, using metal tags for tagging 600 herring, seined at Lochgair in Loch Fyne. No mention is made

of the size, type, or method of attachment of these tags, none of which was recovered.

The senior author (1930, pp. 246—247) tagged 3,071 herring at Halibut Cove in Cook Inlet, Alaska, during the spring of 1927 with monel metal strap tags attached to the caudal peduncle in the same manner as in one of the present experiments. The tag used in the Cook Inlet experiment weighed 0.5 grams, was 3.3 millimeters in width, and about 14 millimeters in length when clinched. No recoveries were made, but the present experiment sheds some light on the possible reasons for this failure.

In spite of the failure of the first attempts it was felt that tagging might well succeed if carefully planned and conducted. To this end the following experiments were carried out: (1) silk ribbons were attached to opercula of 25 fish; (2) threaded through the bodies of 25 fish; (3) flat metal belly tags were inserted in the body cavities of 25 fish; (4) metal strap tags were attached to the opercula of three lots of 75 fish each, and (5) to the caudal peduncles of three lots of 100 fish each. Three lots of 100 fish each without tags were used as controls.

The principal aims of these experiments were:

1. To determine if the mortality of marked herring would be sufficiently low to indicate the feasibility of marking on an extensive scale.
2. To determine the relative merits of different methods of marking herring.
3. To develop a technique for handling and tagging the fish which would be suitable for field conditions.
4. To develop a method of recovering marked herring suitable to the conditions prevailing in south-eastern Alaska.

The experimental tagging was done at Holmes Harbor in Puget Sound, Washington, during the spring of 1932. The first actual field tagging was started in south-eastern Alaska in the summer of 1932. The remainder of the work was done at the United States Fisheries Laboratory in Seattle, Washington.

Description of the marks used in experimental tagging.

A monel metal strap tag was used on the caudal fins and opercles. These tags were of the same type as the larger tags used by the U. S. Bureau of Fisheries on salmon and cod, developed from the ear tag used on cattle and sheep. However, they were much smaller, being 9.4 mm. long when clinched, 2.0 mm. wide, 0.3 mm. thick, and weighing only 0.0675 gr. Each tag bore the letters U. S. B. F. and a serial number. The tags and the pliers used for clinching them are shown in Figure 1.

Flat monel metal tags similar in shape to the celluloid "belly tags" developed by R. A. Nesbit of the U. S. Bureau of Fisheries and used by him in tagging squeteague on the Atlantic coast were used in

the abdominal cavity. These tags were 18 mm. in length, 3.3 mm. in width, 0.7 mm. in thickness, and 0.28 gr. in weight. All of the edges were rounded and smoothed so as not to irritate the peritoneum or internal organs (see Fig. 1).

The experiment included the use of ribbons inserted through the opercle and through the body in the region of the anal fin. These ribbons were approximately 8 cm. long and 6 mm. wide, of two-tone pure dye silk, knotted at one end to prevent slipping through the wound. A curved large-eyed three-sided surgical needle was used in inserting the ribbons through the flesh.

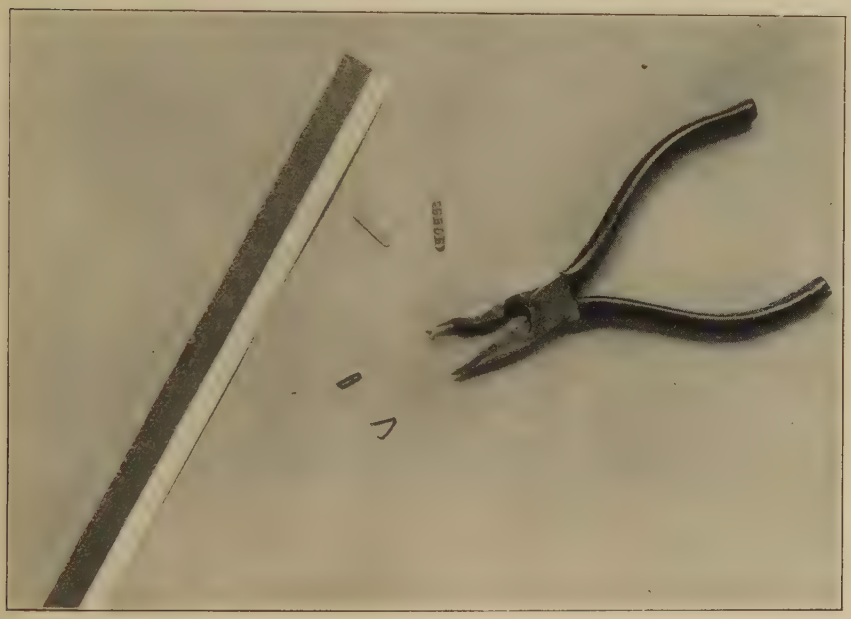

Fig. 1. Two types of monel metal tags and the tagging pliers which were used in marking. There are two large abdominal tags and two small opercle or caudal tags, one crimped and the other open, which are applied by the specially constructed pliers. The scale is in centimeters.

Description of the livebox.

The livebox in which the fish were held during the experiment was a rectangular box 15 feet long, 9 feet wide, and 3 feet deep, and was divided into 9 compartments each measuring 3 feet by 5 feet. The box was made of smooth 2-inch fir planking with a 6-inch by 6-inch beam on the outside of the livebox near the upper edge to give strength against wave action and to support the box in a relatively steady position. To provide for circulation of water, alternate 12-inch

planks were omitted from the bottom planking, and the resulting gaps were covered with heavily soldered and galvanized ¼-inch mesh hardware cloth. By this means two-fifths of the bottom area was screened, providing ample circulation of water, and a solid smooth surface was presented on the sides, preventing the herring from bruising or tearing themselves on the wire (see Fig. 2).

The nine bins in the livebox were each assigned a letter, from

Fig. 2. The livebox in which the herring were retained, anchored in Holmes Harbor.

A to I. Each day during the course of the experiment the livebox was visited and any dead herring removed. During the whole experiment the top of the livebox was covered by locked screens to keep out any marauders.

Procedure used in experimental tagging.

The specimens used in the experiments were obtained from a commercial herring trap. In order to transfer the fish from the trap to the livebox with a minimum of injury, the cork line of the net used in impounding the fish within the trap was placed along one edge of the livebox, which was then sunk below the level of the water, permitting the fish to be driven into the box without handling. The box was then towed away from the trap and anchored.

The fish varied in size from 14.0 to 22.0 cm. in body-length and were mature individuals ripe for spawning.

In tagging, a screen on a wooden frame was inserted across the end of each bin or compartment of the livebox and moved until all of the herring were crowded into one-half of the bin. After 100 fish had been tagged and liberated in the other half of the bin the remaining fish were liberated outside of the livebox. In the control bins the 100 fish were dipped over the screen partition in a dip net without handling.

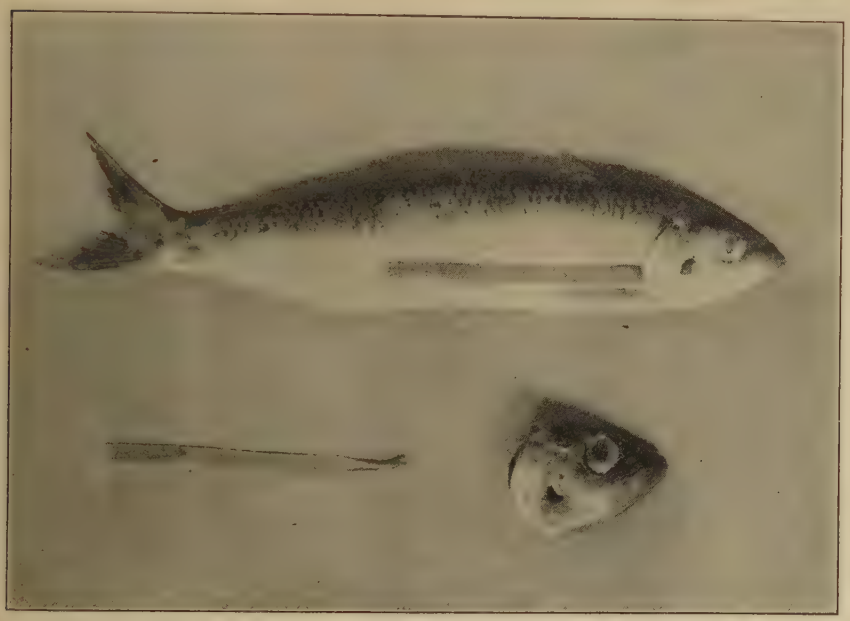

Fig. 3. A herring marked with a ribbon through the opercle. The reason for the failure of this method of marking is indicated by the great enlargement of the opercular wound through which the knot finally slips releasing the ribbon.

The actual tagging was accomplished in the following manner: A dozen or so of the herring were first confined in a large dip net, which was allowed to remain almost entirely submerged within the bin. One at a time the fish were scooped by means of a large saucepan onto a wet cheesecloth stretched over a half-meter ring. The tag was affixed by one operator while the other pressed a wet hand against the fish to keep it from struggling and thus losing scales. The method proved very successful, with some individuals apparently losing no scales, and only a few losing more than a dozen. Immediately after the tag had been affixed, the cheesecloth was tipped, allowing the fish to slide off into the water.

Relative success of the various methods of marking.

Of the 5 methods of marking undertaken in the experiment, the use of opercle and belly tags proved to be the most satisfactory. The two largest contributing factors in the failure of the other three methods were loss of tags and infection of tagging wounds. Although limited space in the livebox prevented use of a sufficient number of belly-tagged and ribbon-marked individuals for an adequate statistical comparison of their mortality as compared to the other two treatments, the conclusions drawn as to their relative success are quite obvious. Data on mortality and loss of tags are given in Table 1.

Table 1.

Mortality and loss of tags of herring undergoing various treatments.

Bin	No. of days confined	Treatment	Original number	Survivors at end of experiment[1])		Survivors losing tags	Survivors without tags removed on thirty-third day	Mortality	Total of dead and of survivors that have lost tags	
				Number	Per cent.				Actual	Per cent.
A	52	Controls	100	97	97			3	3	3.0
B	52	Caudal-tagged ..	100	80	80	6	6	8	20	20.0
C	51	Opercle-tagged ..	75	68	90.7	6		1	7	9.3
C	51	Opercle-ribboned .	25	4	16	16		5	21	84.0
D	51	Opercle-tagged ..	75	73	97.4			2	2	2.7
D	51	Body-ribboned ..	25	11	44	2		12	14	56.0
E	52	Controls	100	97	97			3	3	3.0
F	52	Caudal-tagged ..	100	81	81		5	14	19	19.0
G	51	Caudal-tagged ..	100	77	77	2	14	7	23	23.0
H	46	Opercle-tagged ..	75	64	85.3	1		10	11	14.7
H	46	Belly-tagged	25	21	84	2		2	4	16.0
I	52	Controls	100	92	92			8	8	8.0

[1]) Does not include survivors that have lost tags.

An inspection of the table shows that the ribbon markings were clearly a failure. In the case of the body-ribboned fish only 44 per cent. had survived and retained the ribbons at the end of 51 days. Moreover, all of these survivors were in poor condition, with the tagging wound infected, their death being only a matter of weeks. The mortality of those marked with opercle ribbons was somewhat less, 5 as against 12, but this is easily accounted for by the heavy loss of the opercle ribbons and by the lesser degree of infection taking place in the opercle. The opercle is evidently too thin and brittle to withstand the pull of such a ribbon. As a result the hole in the opercular bones gradually becomes larger until the knot of the ribbon passes through. See Figure 3. With but 4 fish retaining ribbons at the end of 51 days this method is obviously a failure. Although the ribbons remained fairly soft and retained their strength, the colors faded considerably after 51 days in sea water. See Figure 4.

Of the 25 fish marked with belly tags, but 2 died, neither, apparently, dying as a direct result of the tagging. In fact, although the first of the two died on the ninth day after tagging, the incision was already entirely healed, and the same was true of all examined subsequently. It may be noted that two fish were reported as having lost belly tags, the explanation for which may lie in the condition of the fish at the time of tagging. All of the herring were distended

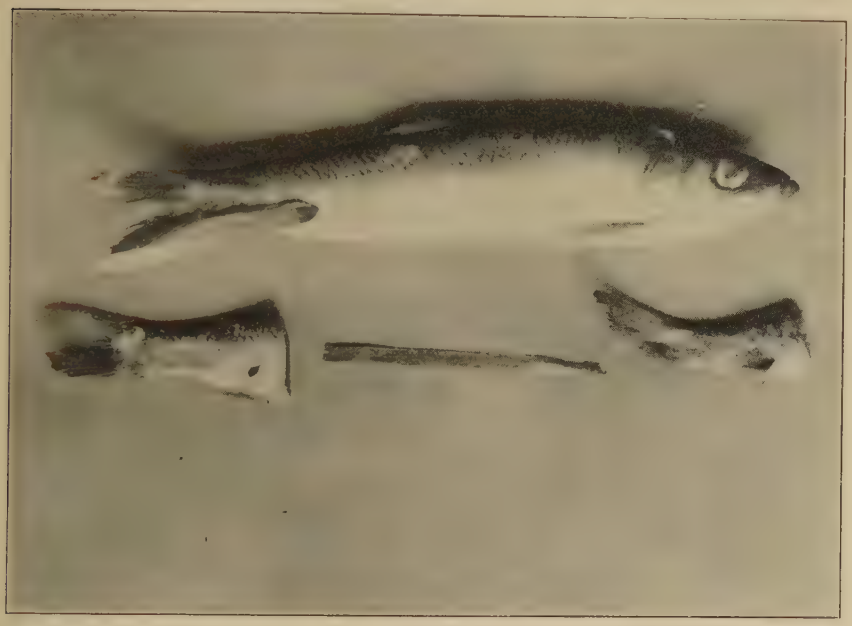

Fig. 4. A herring marked with a ribbon through the body and two examples of the effects of the ribbon on the fish. Note the frayed fins and the large open wounds. The ribbons were removed from these wounds before photographing.

with an abundance of ripe sexual products. In examining the herring after removal from the livebox at the end of the experiment, one female was found to contain a tag in an upright position in the left ovary. From this observation we have deduced that the loss of two belly tags may have been caused by the tags being held upright, possibly by piercing of the gonads during tagging, and thus, being in an upright position, working out through the tagging incision. This difficulty would not exist except during a short period in the spring when the herring contain an abundance of sexual products.

At the end of the experiment the opercle-tagged fish were in excellent condition. In only a few cases were the tagging wounds of any size, the two largest being shown in Figure 5. A few of the

opercle-tagged fish showed a very slight injury to the gill filaments under the tag. This was owing to the presence of a slibht wire edge on many of the tags, which can be corrected to a large degree by having the tags more smoothly finished.

The caudal-tagged herring did not fare as well as the opercle-tagged. Examination of the surviving caudal-tagged fish at the end of the experiment showed clearly that if the tag were placed far

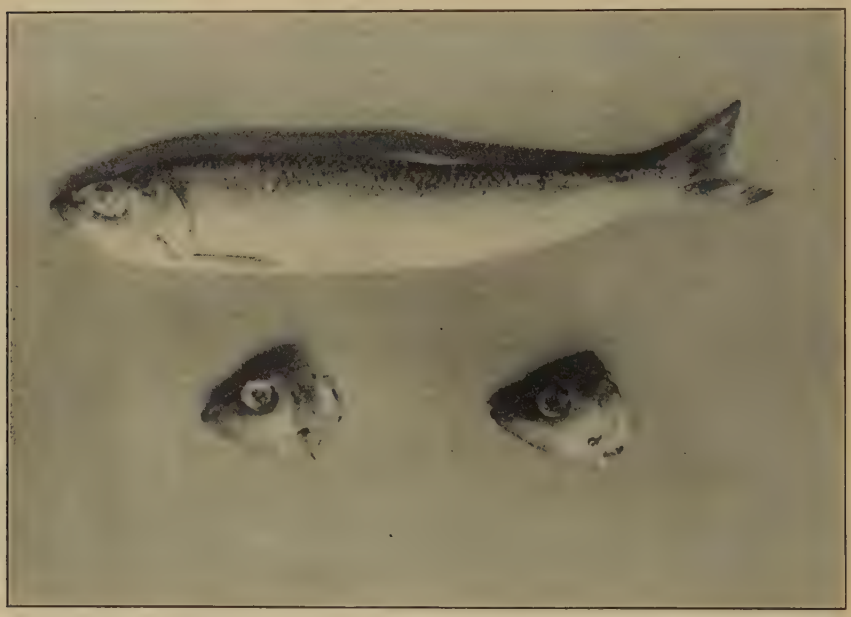

Fig. 5. A freshly marked opercle-tagged herring and two cases that show the effects of the tag on the opercle. These two cases were selected to show the maximum effect, and have much larger wounds than the average.

enough out on the fin to avoid the fleshy portion of the peduncle, the tag usually split the fin, slipped over the end, and was lost. If this were avoided by placing the tag in the fleshy portion of the peduncle a varying amount of infection occurred. In many cases a large blood clot around the tagging wound was noticeable soon after tagging, followed by swelling of the peduncle. In a few cases in which the tags were not properly clinched the swelling was sufficiently pronounced to spread the tags apart. The tags then usually fell off. Probably the majority of the caudal-tagged survivors still retaining their tags at the end of the experiment would have either lost their tags or died within a very few months, as no wound was without some degree of infection. See Figure 6.

In making a statistical comparison of the controls and the two main treatments, i.e., caudal-tagged and opercle-tagged, it was considered proper to compare not the total numbers surviving, but only

the numbers of surviving herring still retaining their tags. In planning the experiment the herring subjected to each of these three treatments were so distributed among the nine bins of the livebox as to have each treatment appear once in each row and once in each column. This procedure was followed in order to have a means of discounting any environmental influences that might affect some of the bins more than others. These environmental influences were kept relatively

Fig. 6. A freshly marked caudal-tagged specimen and two others that have suffered from the effects of tagging. Notice the advances of the infection, one specimen having lost the upper lobe of the caudal fin and the other the entire fin.

constant in each bin by mooring the livebox in the same relative position throughout the experiment. The number of survivors in each bin retaining their tags at the end of the experiment and the percentage they form of the original number is shown in Table 2.

Using the percentage of survivors retaining tags as given in Table 2 the data have been analyzed according to the method of Fisher (1930, pp. 234—237) to determine what portions of the total variance are due to environmental differences between the rows and the columns. The standard deviation of the total, 7.94, is less than 10.24 which is the standard deviation remaining after the elimination of the variance between the rows and columns, thus showing definitely that the environmental effect between different bins of the livebox was so slight as to be disregarded.

Table 2.

Comparative data on controls, caudal-tagged and opercle-tagged herring.

Method of treatment	Bin	Original number	Survivors[1] Actual	Survivors[1] Per cent.	Mean	Standard error
Controls	A	100	97	97		
„	E	100	97	97	95.33	1.67
„	I	100	92	92		
Caudal-tagged	B	100	80	80		
„	F	100	81	81	79.33	1.20
„	G	100	77	77		
Opercle-tagged	C	75	68	90.7		
„	D	75	73	97.4	91.13	3.50
„	H	75	64	85.3		

[1]) Does not include those survivors that have lost tags.

The means of the controls and the two main treatments (see Table 2) were therefore compared according to standard methods (F i s h e r 1930) by dividing their differences by the standard errors and obtaining the probability of *t*.

The caudal-tagged differ very significantly from the controls (P is less than 0.01) and show a significant difference from the opercle-tagged (P is 0.035). The opercle-tagged are thus definitely superior to the caudal-tagged, and show no significant difference from the controls (P is 0.3).

The ribbon-marked and belly-tagged groups are too small to be readily susceptible of statistical treatment. In the case of the ribbon markings no such analysis is necessary to proclaim them failures. In

Table 3.

Causes of mortality in marking experiments.

Method of treatment	Number dying from assigned causes: Loss of Scales	Body bruises	Head injuries	Infected tagging wound	Infected tagging wound as secondary cause[1])	Cause not apparent	Number dead fish examined
Caudal-tagged	9	7		11	6		27
Opercle-tagged	6	3	4				13
Opercle-ribboned	1	2	1		2[2])		4
Body-ribboned				10			10
Belly-tagged	1	1					2
Controls	6	6				2	14
Summary	23	19	5	21	8	2	70[3])

[1]) Included in preceeding columns.
[2]) Gill filaments frayed by ribbon.
[3]) 70 out of 75 of the dead fish were preserved and examined.

the case of the belly tags, it is unfortunate that the experiment was not undertaken on a larger scale. However, the experiment has shown their feasibility. No fish died or suffered from the effect of belly tagging, and, at the end of the experiment, the survivors were in excellent condition.

A great deal of light is thrown on the relative values of the various methods by Table 3, showing the causes of death of the controls and of the herring undergoing the several treatments. Infection of the tagging wound was a primary cause of death only in the cases where the tag was constantly irritating a fleshy portion of the body, namely, the body-ribboned and caudal-tagged fish. In the case of the opercle-ribboned fish the ribbon tended to rub against the soft gill filaments causing them to bleed and to wear away. The smaller number of deaths in this class was due to many of the ribbons dropping from the fish and thus removing the cause of irritation.

It may be noted that no fish died primarily of head injuries expect those bearing tags on the head. This implies that the fish were not handled with sufficient care in tagging and that increased skill should practically eliminate this source of trouble.

Recovery of marked fish.

In every marking experiment certain factors must be considered in order to insure its success, one of which is the length of time over which recoveries are desired or expected. For recoveries over a short period of time fish may be marked by methods that might not be successful over long periods. For example, salmon on their way to the streams to spawn, which can be recaptured over a period of but a few weeks, are ordinarily tagged on the caudal peduncle in the same manner as the caudal-tagged herring in the present experiment. In such cases this method is satisfactory, but it has given a low percentage of recoveries for the Atlantic cod and, also, for troll-caught chinook salmon not on their way to spawn when tagged.

For permanency, the belly tag may prove to be one of the best, but here one is confronted with the difficulty of recovery, except in fishes which are carefully cleaned by hand. In such fish the red celluloid belly tag recently developed by the U. S. Bureau of Fisheries should be excellent.

With the herring, such tremendous quantities are taken and such a small percentage is handled in pickling (the remainder being manufactured into fish meal and oil) that tags must be recovered mechanically in order to insure sufficient returns. To this end an electro-magnet was designed to recover metal tags from the fish meal.

This involved the use of a metal magnetic enough to be easily removed from the constant stream of fish meal flowing over the magnet, yet soft and ductile enough for the manufacture of tags. Monel metal which is usually used for fish tags in America is not

satisfactory for this purpose, not being sufficiently magnetic. The tags used in the field were made from pure nickel which is sufficiently magnetic, has a brighter lustre than monel metal, and after a test of several months has shown no apparent tendency to corrode in sea water.

Herring were first tagged in the field by these methods in south-eastern Alaska during the summer of 1932. In two separate experiments a total of 3,487 herring were tagged and released. In the first experiment using opercle tags 1,034 herring were liberated on July 27th and a second lot of 633 on August 3rd and 4th at Port Conclusion near Cape Ommaney. In the second experiment 824 herring marked with opercle tags and 996 marked with belly tags were released on August 17th at Cape Bendel in Frederick Sound.

Electro-magnets had been installed in each of the five fish reduction plants operated in this district during 1932, before any of the tagged herring were released. However, owing to the mechanical difficulties of installation and faulty construction of the coils only two of the installations were successful. Of the total of 246,900 barrels of herring caught from July 27th to the end of the season on September 30th, 73,600 barrels passed through these two plants. Of this amount 3,400 barrels were used for pickling, leaving 70,200 barrels of herring for reduction. As the magnets were installed in the fish meal line, only this last amount or 28 per cent. of the catch was mechanically searched for tags.

During 1932 the fleet fished only in the vicinity of Cape Ommaney after the middle of July, so that no returns were expected or received from the Cape Bendel experiment.

Ten recoveries were made from the first group of 1,034 liberated July 27th at Port Conclusion, as shown in Table 4.

Table 4.

Recoveries of herring tagged July 27th, 1932, at Port Conclusion.

Date of recovery	Place of recovery	Number recovered	Days out	Distance travelled in miles
July 31, 1932	Port Conclusion	4	2	0
Aug. 4	Larch Bay	1	8	12
Aug. 5	do.	1	9	12
Aug. 13	do.	2	17	12
Aug. 17	do.	1	21	12
Sept. 8	do.	1	43	12

Since 10 tags out of 1,034 were recovered from only 28 per cent. of the fish taken in a 2-month period it is obvious that the method holds promise. The tagging of several thousand specimens should yield enough recoveries to warrant detailed conclusions on migration and intermingling of populations.

Summary.

Because of the delicate structure of the sea herring and the failure of previous attempts at tagging or marking the fish, this species has been regarded as ill-adapted to the study of migrations or racial segregation by direct tagging experiments. The importance of more precise knowledge of the areal distribution of distinct populations of the Pacific herring in Alaska for the purpose of regulating an intensive commercial fishery led to further experiments to determine the feasibility of marking on an extensive scale and to develop a suitable technique that would permit the attachment to the fish of a permanent tag that can be recovered.

A controlled experiment was performed using different types of tags. The mortality of the fish under various treatments and the permanency of the tags was observed in a livebox, and the results were studied statistically. The most suitable type of tag employed in the experiment was a small metal strap tag attached to the operculum of the fish. The mean survival of fish so marked during about 50 days of the experiment exceeded 91 per cent. as compared with 95 per cent. in the untagged controls — a difference not statistically significant. A few fish tagged with internal belly tags of the same material also demonstrated the feasibility of this method of marking.

Recovery of fish tags has been accomplished in south-eastern Alaska, where herring are used extensively for the production of fish meal and oil, by using fish tags made of nickel, which is sufficiently magnetic to be removed by electro-magnets from the stream of fish meal in the process of manufacture. A small field experiment performed in 1932 yielded a sufficient number of recoveries to indicate the feasibility of this method and to encourage further trials.

Note.

Since the acceptance of this manuscript we have received encouraging results from 1933 experiments. In the chief experiment 101 belly tags and 7 opercle tags were recovered during the fishing season (June 1 to September 30) from 2499 of the former and 1470 of the latter, affixed to herring released at Jamestown Bay, (Sitka), between April 21 and April 25, 1933. All of these tags were recovered around Cape Ommaney, giving definite proof of a migration of over 60 miles. The maximum lengths of time from tagging to recovery were 149 days for belly tags and 147 days for opercle tags. The recovery of 4 % of the belly tags and only ½ of one percent of the opercle tags clearly demonstrates the superiority of the former.

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A Method for Marking Cod.

Capt. Hansen's Marking Needle.

By

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FOR many years the type of mark employed in the Danish cod marking work has been two ebonite buttons, one on each side of the gill cover, connected by a silver wire (Fig. II, 6). The silver wire was cut off so as to make it sufficiently pointed to pierce the gill cover.

During the "Dana" expedition to West Greenland in 1925, when the marking of big cod on the banks was planned, we met with the calamity that the silver wire provided proved too soft to penetrate the gill cover of the fish.

In order that we should not have to give up the work in these far-off seas, the "Dana"'s captain, Mr. G. Hansen, tried to find a method whereby the soft silver thread might be used as a connecting link between the two buttons without being itself used to pierce the skin and bones of the gill cover. By means of the primitive tools at hand he made a rather coarse marking needle (see Fig. I,1), which proved excellent in use even though the perforation in the gill cover was a little too big. That year's marking at Greenland was carried out successfully and has yielded about 10 % recaptures, which is a high percentage for that area. The method proving useful, some thinner and more sharply pointed needles of nickel-plated brass were made for the marking next season; later, cold-beaten argentine wire of convenient thickness was used and has proved excellent for making marking needles.

As the use of these marking needles has greatly facilitated the work of marking cod, plaice etc., and as the marking of each fish is performed in a quicker and better way and with less inconvenience to the fish itself than any other method employed by us, I give a short description of the marking needles now in use and our way of using them, so that others may have the opportunity to try them.

A couple of years ago the late Professor Johs. Schmidt demonstrated this marking needle at a meeting in the North Western Area Committee, but as far as I know no other country has yet used it.

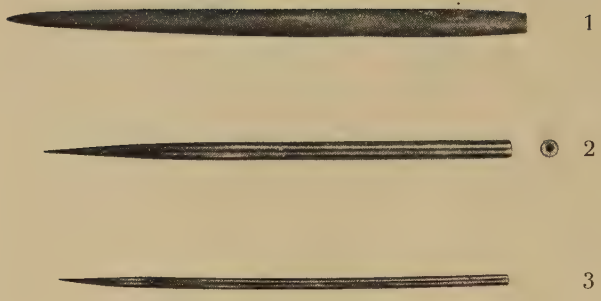

Fig. I. Types of marking needles (see text). Photo. A. Bruun.

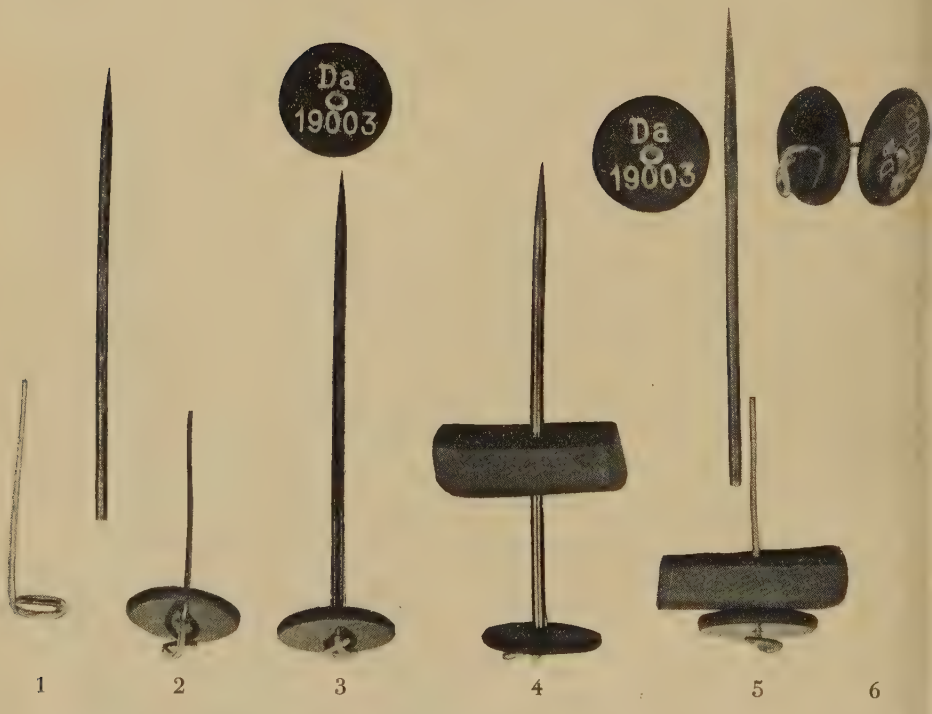

Fig. II. Method in using the marking needle (see text). Photo. A. Bruun.

The marking needle is about 6½ cm. long, the diameter may be 2¼—3½ mm.; a thickness of 2½ mm. is in most cases sufficient to pierce the gill cover bones of even big fishes. The needle is bored to a depth of 4—5 cm. and the hole drilled must be 1¼ mm. in diameter, so that the silver wire in use, 1 mm. thick, can be inserted easily and freely. The needle must be of a convenient metal not too easily affected by salt water, e.g. nickel-plated brass or cold-beaten argentine wire, as already mentioned.

The figures show the way of using the marking needle. The silver wire is cut off in 5 cm. lengths and an eye formed by means of a pair of nippers with cylindrical jaws (Fig. II, 1); an unmarked ebonite button is threaded on this silver wire (Fig. II, 2) and the marking needle is pushed down over the wire (Fig. II, 3). The needle is held firmly in the right hand, the thumb placed on the ebonite button on which the eye of the wire rests, the gill cover of the fish is lifted with the left hand and from the inner side of this the needle is pushed through it (Fig. II, 4). It is possible to do this quickly and exactly at the spot on which the mark is required to be placed, through one of the flat opercular bones, for instance, at a fair distance from the edge of the gill cover so that the mark is not afterwards torn out. When the needle has been passed through the gill cover it is unthreaded from the wire, which now protrudes from the outside of the gill cover (Fig. II, 5); the ebonite button bearing the number is then placed on the silver wire with the number outside and the wire bent round by means of nippers with cylindrical jaws. It is important that the eye in the wire (both on the inside and the outside of the gill cover) is so formed that the free end is placed nearest to the button; this prevents even soft silver wire from being straightened out so that the button slips off. (Fig. II, 3 shows clearly the position in which the free end of the silver wire ought to be left.) If a man can be spared to thread the needles with buttons ready for use, to mark a cod or plaice requires less than 30 seconds. This method is by far the best and surest of all the methods which we have employed; big cod have been recaptured up to seven years after having been marked in this way.

Note.

Measurement of Submarine Illumination.

A review, by V. E. Shelford, of two papers of W. R. G. Atkins and his co-workers appeared in Vol. VIII, April, 1933, of the Journal du Conseil. Since the review was almost altogether on the apparatus, it seems desirable, in order to do justice to the excellent work done by these experimenters, to supplement the review by a more complete statement of their experimental apparatus and procedure.

In the first place, the reviewer does not differentiate between two separate and distinct methods of measuring submarine illumination. Gall and Atkins, and Atkins and Poole have employed two methods of observation. One consists of a balanced potentiometer circuit by means of which they measure the potential drop across a resistor which gives the value of the photoelectric current at the time of the measurement. This current yields, through the cell calibration, the instantaneous value of the illumination at the cell. This method of measuring currents of the order obtained by a submerged cell is a standard arrangement for such measurements and has given good results in the hands of the users. The second is an integrating circuit in which a condenser, in parallel with a neon lamp, is charged by the current of the submerged cell for whatever time is necessary to build up its potential to the flash-over potential of the neon lamp. The time required to flash the lamp will depend upon the capacitance of the circuit and the intensity of the radiation falling on any particular cell. By counting the flashes of the lamp for a finite time, viewed through an eyepiece, together with the cell calibration, this circuit furnishes a value for the illumination at the cell over this period of time. The apparatus is *quite simple* and by varying the capacitances in parallel with the lamp will operate over a wide range of illuminations and quite as well for high values of illuminations as for low ones. The circuit and the reading device (an eyepiece) are not necessitated by the smallness of the photoelectric current and will, with the proper selection of the capacitance, function as readily for large currents as for small ones.

The question might be raised as to the capacity effect of the cable leading from the submerged cell to the ship's deck which has, for different depths of the cell, a variable fraction of its total length in salt water.

What use the reviewer has in mind for a "direct reading galvanometer" in this circuit is not quite evident.

Excellent schematic diagrams of both circuits are given by Atkins in a recent paper in the Journal du Conseil (Vol. VII, p. 201 and p. 203, 1932).

In the third paragraph of the review of the second paper, the reviewer expresses regret that the cells were not properly standardized for *biological use*. It is well known in photoelectric emission that the rate of emission of electrons from a photosensitive surface is exactly proportional to the intensity of the radiation falling on that surface, and further, the energy of any emitted electron is absolutely independent of the intensity of the light but depends upon the frequency of the incident radiation. Now, as long as the current-intensity-frequency relationships have been established for a given cell, which have been done by these experimenters, then, under *any circumstance* a measurement of the current produced by radiation of a definite wave-length will furnish a knowledge of the intensity of illumination produced by that radiation.

In regard to the method employed by Atkins for housing his sea photometer, it has been effected in order to measure the vertically downward illumination. (The experience of the writer has been that the orientation of a submerged photoelectric cell is very much at the mercy of currents in the water. This is certainly the case in the inshore waters of the Pacific Northwest.) A flat, thin, heavy device mounted by means of a sling, such as is used by Atkins, furnishes considerable assurance that it will maintain its relative position in the water at different depths. At any rate, the photosensitive surface is more likely to maintain a definite position when so mounted than if the cell were exposed directly in the water. For any considerable change in the orientation of the cell, the photocurrent might be due to components of the vertically downward illumination as well as to light scattered in a horizontal direction.

The use of a deck photometer during submarine measurements is to be commended. Even on clear, cloudless days, the intensity of the incident light may vary by a considerable amount in a short time.

The work of Atkins and his colleagues has been of great value in its contribution to the knowledge of submarine illumination as well as in guiding other workers in this field of solar radiation.

C. L. Utterback,
Oceanographic Laboratories,
Seattle, Washington.

Reviews.

(Various). "Physics of the Earth." — V. Oceanography. Bull. of the National Research Council. No. 85. Washington, D. C., 1932.

Die Ozeanographie hat sich im letzten Jahrzehnt mehr und mehr von einer geographischen Disziplin zu einem selbständigen Zweig der Geophysik entwickelt. Hierin liegt die Tatsache begründet, dass wir in der geographischen Literatur die Ergebnisse der modernen Ozeanographie nicht mehr zusammenfassend dargestellt finden; andererseits fehlen auch bislang in der geophysikalischen Literatur umfangreichere Zusammenfassungen ozeanographischer Forschungsergebnisse. So besteht — besonders in der Literatur englischer Sprache — das dringende Bedürfnis nach einem ozeanographischen Handbuch, das geeignet ist, einem Wissenschaftler, der nicht Spezialist auf dem betreffenden Gebiete ist, einen umfassenden Überblick über den gegenwärtigen Stand und die noch zu lösenden Probleme der Ozeanographie zu geben. Dieses Ziel steckt sich der vom "U. S. A. — National Research Council" herausgegebene umfangreiche Band "Oceanography", der als 5. Bericht im Rahmen einer ganzen Serie von geophysikalischen Bulletins zur "Physik der Erde" erscheint.

In diesem Werke werden von 18 Mitarbeitern die verschiedenen Gebiete der physikalischen und chemischen Ozeanographie und ihre Beziehungen zu den Nachbarwissenschaften, Meteorologie, Biologie und Geologie in 16 Kapiteln behandelt. Es liegt im Wesen eines solchen Sammelwerkes, dass die Stoffbehandlung keine systematische und vollständige ist, und dass die einzelnen Autoren sich ihrer Aufgabe sowohl was Ausführlichkeit als Art der Darstellung anlangt, in ganz verschiedener Weise entledigen.

Nach einer kurzen Einleitung, in welcher N. H. Heck die Domäne der Ozeanographie und den Aufbau des Werkes skizziert, gibt im zweiten Kapitel G. W. Littlehales eine flüssige Beschreibung der Hauptzüge der ozeanischen Bodenkonfiguration, wobei er sich im wesentlichen auf die "Carte Générale Bathymétrique des Océans" (Monaco) stützt, aber auch neuere Lotergebnisse und Spezialuntersuchungen heranzieht. Man bedauert bei diesem Aufsatz das Fehlen jeglicher graphischen Veranschaulichung in Karten oder Profilen und stellt ferner fest, dass die morphometrischen Angaben über die Areale der einzelnen Tiefenstufen auf einer älteren Berechnung von Krümmel (1907) beruhen. Auf Grund der flächentreuen Tiefenkarten von Groll (1912) hat Kossinna (1921) neue wesentlich exaktere Werte für die Areale der Tiefenstufen ermittelt. Auch darf erwähnt werden, dass das Gesamtareal des Weltmeeres mit grosser Annäherung 361.1 Millionen km.^{2} beträgt (und nicht 365.5 Millionen km.^{2}, wie Littlehales angibt).

Kapitel 3 enthält eine klare, knappe Zusammenfassung (14 Seiten) über die Beschaffenheit und Verbreitung der Tiefsee-Sedimente durch L. W. Collet, die auf den grundlegenden Arbeiten Murrays beruht.

Die physikalisch-chemischen Eigenschaften des Meerwassers werden im 4. und 5. Kapitel von Th. G. Thompson und R. J. Robinson ausführlich (140 Seiten) und unter Verwertung der neuesten Literatur behandelt. Durch die zahlreichen Tabellen und Diagramme und durch die systematische Berücksichtigung der einzelnen Faktoren und Elemente bieten diese beiden Kapitel eine Fülle von Material, dessen klare und übersichtliche Zusammenstellung dankbar begrüsst werden wird.

Den umfangreichsten Teil des Werkes (202 Seiten) machen die 5 Kapitel des Abschnittes "Bewegungen des Meeres" aus, wodurch die grosse Bedeutung zum Ausdruck kommt, welche die dynamische Betrachtungsweise in der modernen Ozeanographie besitzt. In leicht verständlicher Form und unter Verzicht auf theoretische und mathematische Ableitungen geben H. A. Marmer und R. S. Patton einen klaren Überblick über die Wellen und Gezeiten. Besonders wertvoll ist die Zusammenfassung von G. F. McEwen über die Grundprinzipien der dynamischen Ozeanographie, die eine ausgezeichnete Einführung in diesen wichtigsten Zweig der modernen Meereskunde darstellt. In der englischen Literatur wird besonders auch der Überblick über die gegenwärtige Kenntnis von der ozeanischen Zirkulation durch A. Schumacher begrüsst werden, da ja die Spezialuntersuchungen zu diesem Probleme im wesentlichen in deutscher Sprache erschienen sind. (In diesem Aufsatze von Schumacher vermisst man unter den zahlreichen Vertikalschnitten der Temperatur und des Salzgehaltes die Längsschnitte durch den Pazifischen Ozean, auf die sich der Autor im Text bezieht.) Als Ergänzung zu dieser übersichtlichen Darstellung der vertikalen Schichtung und der Tiefenzirkulation wäre eine systematische Behandlung der Oberflächenströmungen und der horizontalen Verteilung von Temperatur und Salzgehalt sehr erwünscht. Schliesslich wird allen Ozeanographen die kurze, klare Zusammenfassung von E. H. Smith über das Meereis willkommen sein.

In den Kapiteln 11 bis 13 werden vornehmlich auf Grund der Erfahrungen der "Carnegie"-Expedition von F. M. Soule, W. E. Parker und C. O. Iselin in kurzen und gut illustrierten Aufsätzen die Methoden und Instrumente der praktischen Ozeanographie erläutert.

Der letzte Hauptabschnitt ist den Beziehungen der Ozeanographie zu den anderen Wissenschaften gewidmet und besitzt, da bisher diese Beziehungen kaum zusammenfassend dargestellt wurden, ein besonderes Interesse. Verhältnismässig ausführlich (64 Seiten) und recht anschaulich wird von Ch. F. Brooks die Beziehung zwischen Ozeanographie und Meteorologie an zahlreichen gut ausgewählten und illustrierten Beispielen erläutert, während in kurzen Streiflichtern A. G. Huntsman die Beziehungen der Meereskunde zur Biologie aufhellt.

Im letzten Kapitel gibt Ch. Schuchert vornehmlich auf Grund seiner eigenen Forschungen eine Übersicht über die Periodizität der ozeanischen Transgressionen und über die Hauptergebnisse seiner Paläogeographie, deren Hypothesen wahrscheinlich nicht von allen Forschern, die sich mit der Entstehung der Ozeane befassen, geteilt werden dürften.

Zusammenfassend ist zu sagen, dass der Gedanke des "National Research Council" die neuesten Forschungsergebnisse der Ozeanographie, wie überhaupt der Geophysik durch ein Sammelwerk solcher Einzelbeiträge aus der Feder von Fachleuten übersichtlich darstellen zu lassen, als ein durchaus glücklicher anzusprechen ist. Man kann nur wünschen, dass dieser Band durch weitere Ergänzungen von Zeit zu Zeit auf den neuesten Stand gebracht wird. Das

vorliegende Werk ist zugleich ein Zeichen dafür, dass sich das Interesse für die Meereskunde in den Vereinigten Staaten in den letzten Jahren ausserordentlich belebt hat.

G. Wüst.

K. Buch. "Untersuchungen über gelöste Phosphate und Stickstoffverbindungen in den Nordbaltischen Meeresgebieten." Havsforskningsinstitutets Skrift No. 86. S. 1—30. Helsingfors, 1932.

Auf den vom Meeresforschungsinstitut in Helsingfors in der nördlichen Ostsee jährlich durchgeführten Terminfahrten wurden vom Verfasser seit 1928 auch die als Planktonnahrung bedeutsamen Minimumstoffe untersucht. Die Ergebnisse der Phosphat-, Nitrat-, Nitrit- und Ammoniak-Bestimmungen aus den vier Jahren 1928—1931, die grössten Teils schon früher mit den Fahrtbeschreibungen veröffentlicht wurden, sind noch einmal tabellarisch zusammengestellt. Die Analysenmethoden sind z. T. von B u c h selbst bereits früher beschrieben worden (Nitrit, Ammoniak), z. T. wurden die allgemein üblichen Methoden angewendet (Nitrat, Phosphat).

Wie im Sommer zu erwarten, war das Oberflächenwasser sehr arm an Phosphat und Nitrat; im Mittel waren vorhanden 2—6 mg. P und 3—23 mg. N pro $m.^3$, je nach dem Meeresgebiet. In der Tiefe nimmt der Nährstoffgehalt sprunghaft zu, am stärksten in der mittleren Ostsee, wo er auf 50 mg. P und 82 mg. N/$m.^3$ steigt, am schwächsten im Bottnischen Meerbusen. Dieser nimmt überhaupt eine gewisse Ausnahmestellung ein, die offenbar durch die morphologischen Verhältnisse bedingt ist. Durch flache Schwellen wird die nördliche Bucht von der übrigen Ostsee getrennt, sodass das an der Oberfläche nach Süden abfliessende Wasser nicht durch das nährstoffreiche Tiefenwasser, sondern durch relativ verarmtes Wasser aus geringen Tiefen ergänzt wird. Besonders das Phosphat fehlt aus diesem Grunde, sodass keine merkliche Planktonentwicklung entstehen kann, obwohl durch Zuflüsse von Land reichliche Mengen Stickstoffverbindungen zur Verfügung stehen. Diese N-haltigen Zuflüsse bewirken vor allem eine Anreicherung von Ammoniak in der Bottensee, besonders in der Tiefe, da die eiweisshaltigen Humusstoffe nach der Ausflockung zu Boden sinken und dort zersetzt werden. In allen übrigen untersuchten Gebieten der Ostsee ist die Ammoniakverteilung normal, d. h. seine Konzentration nimmt mit der Tiefe ab. Auch hier stammt es zum grossen Teil wohl vom Lande, zum Teil aber wohl aus zersetztem Plankton, wie wir es in der offenen See annehmen müssen.

Nitrit findet sich nur in sehr geringen Mengen (1—2 mg./$m.^3$) und zeigt keine irgendwie ausgeprägte Verteilung.

Die vorliegende Untersuchung gibt zum ersten Male einen Einblick in die sommerlichen Nährstoffverhältnisse der Ostsee, die wesentlich verschieden sind von denen des offenen Ozeans und seiner Randmeere. Es dürfte von grösstem Interesse sein, wenn an geeigneten Punkten auch der jahreszeitliche Verlauf der Minimumfaktoren verfolgt werden könnte.

H. W.

L. H. N. Cooper. "Chemical Constituents of Biological Importance in the English Channel, November, 1930, to January, 1932. Part I. Phosphate, silicate, nitrate, nitrite, ammonia." Journ. Mar. Biol. Assoc. N. S., Vol. XVIII, No. 2. Plymouth, 1933.

Die Arbeit berichtet über die Fortsetzung der von A t k i n s seit 1923 durchgeführten Untersuchungen über die Nährstoffverhältnisse in der Mündung des Englischen Kanals. C o o p e r hat den Kreis der Untersuchungen

durch regelmässige Bestimmungen des Nitrits, Ammoniaks, Sauerstoffs und der Titrationsalkalinität (vergl. folg. Ref.) wesentlich erweitert und damit ein bisher wohl einzig dastehendes Material relativ kurzabständiger Beobachtungen über den jahreszeitlichen Verlauf der für das Plankton bedeutsamen Stoffe geschaffen.

Die Hauptnährstoffe *Phosphat* und *Nitrat* wiesen im grossen und ganzen denselben Gang auf wie in den vorhergehenden Jahren. Im einzelnen zeigten sich jedoch Unterschiede, die über das Zufällige hinausgehen und Licht auf den Mechanismus der Regeneration der Nährstoffe werfen. So hatte z. B. 1931 schon eine zeitlang die Frühjahrswucherung eingesetzt, wie aus dem Abfall des Phosphats zu schliessen war, während der Nitratgehalt nicht nur nicht gesunken sondern sogar deutlich gestiegen war. Cooper nimmt nun an, dass während dieser Zeit die letzte Phase der Regeneration des Nitrats, die über viele Stufen verläuft, noch nicht beendet war und den Verbrauch überkompensierte. Beim Phospat geht die Regeneration offenbar sehr schnell vor sich. Nach Aufhören einer Planktonwucherung, ja häufig schon vorher, wird aus den abgestorbenen Zellen anorganisch gebundener Phosphor frei, sodass Verbrauch und Regeneration sich die Waage halten können. Beim Stickstoff jedoch ist während des Sommers bis in den Herbst hinein noch keine Neubildung von Nitrat zu bemerken. Während dieser Jahreszeit sind daher die Nitratgehaltsänderungen ein besseres Mass für die Planktonproduktion als die Änderungen im Phosphatgehalt.

In Einklang mit diesen Beobachtungen über die Regeneration der Nitrat- und Phosphat-Verbindungen steht das Verhalten des *Nitrits* und *Ammoniaks*. Im Winter 1930—31 und im Herbst 1932 trat das Ansteigen der Konzentrationen von Ammoniak, Nitrit und Nitrat hintereinander ein. Damit ist wohl zum ersten Male im Meere die zeitliche Aufeinanderfolge der Eiweissabbaureaktionen nachgewiesen worden. Die Ammoniakbildung fand in der Hauptsache in den Oberflächenschichten statt, eine Beobachtung, die in guter Übereinstimmung mit den Ergebnissen anderer Autoren steht. Bemerkenswert ist die Feststellung, dass Nitrit wie auch Ammoniak bei Nitratmangel unmittelbar vom Plankton als Stickstoffquelle benutzt werden. Dadurch ist eine von Schreiber u. a. in bakterienfreien Reinkulturen gefundene Tatsache auch für natürliche Verhältnisse bestätigt worden.

Auch bei der *Kieselsäure* geht die Regeneration schneller vor sich, als man erwarten sollte. In den meisten Jahren findet schon im August eine Wiederauflösung der im Frühjahr nach der ersten Diatomeenwucherung abgesunkenen Kieselschalen statt, die durch ein Ansteigen des Silikatgehalts des Bodenwassers gekennzeichnet ist. Umgekehrt hat der Silikatgehalt offenbar einen Einfluss auf den Habitus der Diatomeen, denn die im März bei hohem SiO_2-Gehalt gefangenen Organismen hatten dicke, die später im Mai gebildeten nur dünne Kieselschalen.

Der Verfasser gibt ausführlich seine Erfahrungen mit den angewandten Methoden wieder, von denen folgende erwähnt seien. Bei der Nitritbestimmung (nach Griess-Ilosvay) wurde jede Möglichkeit einer Verunreinigung dadurch ausgeschlossen, dass die Probeflaschen selbst als Kolorimetergefässe für Seewasser und Standards verwendet wurden. Auf diese Weise konnte die erstaunliche Empfindlichkeit von 0.02 mg.N/m.^{3} erreicht werden! Auch bei der Kieselsäure wurde die Empfindlichkeit durch Verwendung 60 cm. langer Rohre gesteigert, sodass noch 20 mg. SiO_2 mit Sicherheit nachweisbar waren. Für die Ammoniakbestimmung wurde die Weinsäure-Methode verwendet, welche nach Einführung einiger kleiner Modifikationen einwandfreie Resultate gab. Es empfiehlt sich daher, sich nach der vom Verfasser ausführlich beschriebenen Arbeitsweise zu richten. Es wurde ferner festgestellt,

dass Aminosäuren und Alkylamine die NH_3-Bestimmung nicht stören ausser Methylamin, das etwa $^1/_{10}$ der Farbintensität von Ammoniak mit Nessler gibt.

Zum Schluss stellt der Verfasser einen Vorschlag zur Diskussion, die Konzentration der Phosphor- und Stickstoff-Verbindungen in Milligrammatom pro $m.^3$ auszudrücken, wodurch die verschiedenen Verbindungen unmittelbar quantitativ miteinander vergleichbar werden. *H. W.*

L. H. N. Cooper. "Chemical Constituents of Biological Importance in the English Channel, November, 1930, to January, 1932. Part II. Hydrogen-ion concentration, excess base, carbon dioxide and oxygen." Journ. Mar. Biol. Assoc. N. S., Vol. XVIII, No. 2. Plymouth, 1933.

Gleichzeitig mit der terminmässigen Untersuchung der Minimumstoffe (vergl. vorstehendes Ref.) bestimmte der Verfasser das pH, den Sauerstoffgehalt und die Titrationsalkalinität. Aus dem pH wurde mit Hilfe von Temperatur und Salzgehalt nach den neuen Tabellen von K. Buch und Mitarbeitern die freie Kohlensäure, der Kohlensäuredruck und die Gesamtkohlensäure ermittelt. Der jährliche Gang dieser ebenfalls vom Plankton beeinflussten Faktoren hat naturgemäss grosse Ähnlichkeit mit dem Gang der Phosphor- und Stickstoff-Verbindungen. Das Oberflächenwasser war hinsichtlich der Kohlensäure während des Winters nahezu im Gleichgewicht mit der Atmosphäre. In der übrigen Zeit herrschte eine deutliche Untersättigung an CO_2 infolge der starken Assimilation, durch die gleichzeitig eine grosse Menge Sauerstoff in Freiheit gesetzt wurde. Dieser Sauerstoff entwich während des Sommers in beträchtlicher Menge in die Atmosphäre. Eine entsprechende Quantität Kohlensäure musste demnach aus der Luft aufgenommen werden, wenn es sich um ein in sich geschlossenes System handelt. Die aufgenommenen Kohlensäuremengen sind aber bedeutend grösser, als man aus der Differenz der Kohlensäuredrucke in Luft und Wasser mit Hilfe der Invasionskoeffizienten von Chr. Bohr errechnet. Entweder sind diese also auf das Meer nicht anwendbar, oder aber das Untersuchungsgebiet ist nicht als ein in sich geschlossenes System zu betrachten.

Nach dem Vorgang von Atkins ermittelt der Verfasser aus dem jährlichen Verbrauch an Phosphor, Stickstoff, Kohlenstoff sowie aus dem freigewordenen Sauerstoff die Produktion an Phytoplankton und kommt zu überraschend übereinstimmenden Ergebnissen (ca. 1400 Tonnen pro Quadratkilometer bei 72 m. Wassertiefe). Wenn man die gleiche Rechnung unter Benutzung des Silikat-Verbrauchs anstellt, so erhält man etwa $^1/_{10}$ dieses Wertes. Da nun aber der Anteil der Diatomeen am Gesamtplankton bedeutend grösser ist, muss man daher annehmen, dass eine gewisse Menge Kieselsäure mehrmals im Verlaufe eines Jahres den Lebenskreislauf durchmacht. Wenn man die obige Zahl mit der jährlich gefangenen Fischmenge vergleicht, ergibt sich, dass etwa nur 0.06 % der Phytoplanktonproduktion als Fisch dem Meere entzogen wird in einem Gebiete, in dem Anzeichen der Überfischung sich bemerkbar machen.

Die jahreszeitlichen und örtlichen Änderungen der Titrationsalkalinität waren zwar sehr klein, aber es zeigte sich doch deutlich im Sommer eine Zunahme der Alkalinität nach dem Boden zu, ähnlich wie sie bereits aus dem Atlantischen Ozean als Folge der Auflösung von Kalk bekannt ist.

H. W.

A. Defant. "Die Gezeiten und inneren Gezeitenwellen des Atlantischen Ozeans." Wiss. Ergebnisse der Deutschen Atlantischen Expedition 1925—1927. Bd. VII, Teil I. Berlin und Leipzig, 1932.

During the expedition the "Meteor" anchored at 9 stations in the open sea in depths between 2100 and 4600 metres. The periods of anchorage ranged from 27 up to 64 hours. They were used chiefly for measurement of currents — with the log and with current-meters of various construction — and for investigation, by means of repeated hydrographic series of temperatures and salinities etc., of the internal movements of the water-layers, which have for the last 20 years attracted increasing attention. Results of these investigations, which were in their kind unequalled, form the chief subject of the important volume under review. It opens with a discussion, from a general point of view, of the motions of an anchored ship and their influence on the measurements of current. On one point the writer does not share the views here presented, viz. in considering the initial effect of a motion which is just beginning; the matter does not, however, seem on any essential point to influence the final results of the work.

From experience at the earlier stations the scheme of observations was gradually made more comprehensive at the later stations. The latter are for this and other reasons particularly instructive. The reader will appreciate the author's arrangement in analysing them first, before examining the observations taken at the earlier stations.

One of the chief purposes of the current-measurements seems to have been the direct investigation of the general circulation of the waters of the Atlantic. The present volume does not contain conclusions touching that problem, and only the average velocities and directions of the current at the various depths of observation are stated. The important problem of the connection between wind and current is occasionally touched upon, e.g., in the case of anchor station 241, but with no considerable positive result. The problem is certainly a complicated and difficult one. In the case of the above-mentioned station, for instance, the winds varied considerably during the three days that the anchorage lasted, and since on the latitude of that station half a pendulum day is no less than 7½ days, a close relationship between the currents and the *simultaneous* wind could not be expected to exist.

The expedition had the good fortune to observe on one of its equatorial anchor stations (No. 254) a large, single, internal wave, which in the course of some 8 hours passed the station, and the striking phenomenon is made the subject of a most interesting analysis. Strange to say, the wave manifested itself in vertical displacements of the water-layers only. No noticeable alterations of the currents were observed while the wave was passing, although at 50 metres (where measurements were repeatedly carried out) it ought to have caused rather considerable currents — up to at least 20 cm. per second according to the present writer's calculation.

The greater part of the volume is devoted to a comprehensive study of the periodic movements of the water. It is worth noticing that, in addition to other measurements, the observation every 10 minutes of the ship's head at anchor proved to be very useful. It should be mentioned that at most anchor stations there was found a top layer of nearly homogeneous water, 20 to 120 m. thick and separated from the Deep Water by a transition layer with very rapid vertical variations of temperature and density and (in most cases) of salinity.

As far as the short-period internal movements are considered, particular

interest is attached to the last anchor station 288, where observations were carried out for nearly 40 hours according to a comprehensive scheme. The present writer has on a previous occasion thrown doubt upon the reality of certain short-period waves which, according to a preliminary report, were found at this station. The complete analysis now published gives increased credibility to these waves, additional evidence being obtained from the observations of the ship's head, which allowed the construction of periodograms. The author discerns three periods of about 1.9, 2.9 and 5.5 hours, of which the latter manifests itself quite clearly in the currents and reappears in the hourly observations of temperature and salinity in various standard levels. The difference of phase between current and vertical displacement of the water-layers indicates *progressive* waves proceeding in this case in a northerly direction. The author is certainly right when he considers these short-period waves as an incidental phenomenon that may be absent on another occasion at the same station or may reappear with quite different periods and amplitudes and direction of propagation. Similar waves are observed once or twice at other anchor stations.

At most stations the results of the measurements did not suggest periods other than 12 and 24 hours. Since the series of observations were not long enough for an empirical distinction between solar and lunar periods, *lunar* diurnal and semidiurnal periods were anticipated except for the variation of temperature and salinity of the *surface water*, in which case the period of 24 solar hours was assumed.

The determinations of the daily variation of temperature deserve great attention. They are more reliable than earlier determinations and give lower values than these. The range of variation was found to be about 0.4° at equatorial stations and gradually decreased towards the poles, the value 0.16° being observed at the latitude of 21°. At some stations, where the depth of the homogeneous top-layer exceeded 50 metres, the daily variation of temperature could be determined in this latter level as well, and the range of variation was found to be something like 0.05°. For three of these stations the investigation further led to calculation of the eddy-conductivity ("Austausch") with results lying between 117 and 410. (A still greater value might have been given alternatively.) A comprehensive study of the variations of temperature of the surface water and of the air confirmed H a n n's statement, that both media are heated and cooled independently, but parallel with one another, by radiation.

The investigation of tidal motions — horizontal currents as well as vertical displacements of the water-layers — is extremely interesting, since it is the first time that measurements of tidal currents have been carried out at stations distributed over a large area of the deep open ocean. The reviewer is inclined on some points to regard the author's confidence in his analysis as optimistic, but this remark has reference to details only and not to the general results. Semidiurnal internal waves, which have previously been found by Danish investigators in the Faeroe-Shetland Channel, were found, and comprehensively studied, at almost all the "Meteor"'s anchor stations, and their reality cannot be doubted, even if the semidiurnal period may occasionally, as, e.g., at stat. 176, seem somewhat arbitrary. To judge from the phase difference between the currents and the vertical displacements they seem as a rule to be progressive waves. Diurnal internal waves have also been analysed. The author furthermore develops theoretically an interesting type of internal wave under the influence of the earth's rotation. The question how such tidal internal waves could be excited — or maintained against friction — by tide-generating forces seems, however, to be still as

mysterious as ever. The only possibly acceptable explanation that I am aware of — Zeilon's "secondary boundary waves" — seems rather unlikely, and it would certainly be no easy task to put it to test by means of the observations here referred to.

The reader is puzzled by other seeming or real periodicities of unknown origin. The variations of the number of plankton organisms in the water in standard depths are interpreted as having a semidiurnal periodicity and depending on the periodic vertical displacements of the water-layers. To one of the series examined, which refers to the plankton content of *surface* water, this explanation cannot, of course, be applicable; and even in the cases of the other series the reviewer does not find the empirical evidence of a semidiurnal periodicity very strong.

The observations on tidal currents command the greatest respect, and the theory of the Atlantic tides has now, thanks to the "Meteor" Expedition, a much more solid foundation than before. Various conclusions from the theory are confirmed. Thus the direction of the semidiurnal as well as of the diurnal current as a rule turned *cum sole*, and also the ratios between the axes of the elliptical orbits are found to be in a satisfactory agreement with theory. The maximum velocity of the semidiurnal component of the current generally lay between 5 and 10 cm. per sec. but exceptionally ran up to nearly 20 cm. per sec. Approximate isochrones for the semidiurnal tides are — for the first time — drawn within the whole region between 30° S. and 30° N. The geographical distribution of phase and amplitude confirms — or at any rate is in good agreement with — Defant's views on the Atlantic tides as produced by the superposition of progressive waves, coming from the south, and standing waves. It has even been possible to a certain extent to draw up his theory numerically. Since a detailed account of the matter would extend this review beyond reasonable limits, the reader must, however, be referred to the original work.

In spite of the important results already arrived at, and in spite of the often surprisingly good agreement between observation and theory, the difficult problems of tides and internal waves could not, of course, be expected to be definitively settled. There are still serious questions which must be answered; and for that purpose it will again be necessary to fall back upon Defant's work, in which the reader will find an ample fund of suggestive observations.

V. W. Ekman.

George F. McEwen. "Results of evaporation studies conducted at the Scripps Institution of Oceanography and the California Institute of Technology." Bull. Scripps Inst. of Oceanog., La Jolla. Tech. Series, Vol. 2, No. 11, pp. 401—415. Berkeley, California, 1930.

Der Aufsatz gibt eine knappe Übersicht über sehr umfangreiche theoretische und praktische Studien zum Problem der Verdunstung, die auf McEwens Anregung von verschiedenen Mitarbeitern, N. W. Cummings, I. S. Bowen, B. Richardson und C. Montgomery durchgeführt worden sind. —

Die statistischen Vorstudien von Cummings an umfangreichem älteren Beobachtungsmaterial liessen eine klare Abhängigkeit der Verdunstungshöhe von der Lufttemperatur, dem Wind und insbesondere der Luftfeuchtigkeit nicht erkennen — angesichts der Methode der meisten früheren Untersuchungen ein bemerkenswertes Ergebnis. Daraufhin auf thermodynamischer und molekulartheoretischer Grundlage vorgehend, formulierte Cummings zu-

nächst einen dem Le Chatelierschen Prinzip ähnlichen Grundgedanken: Bei jeder Änderung der Windgeschwindigkeit oder Luftfeuchtigkeit (ohne gleichzeitige Änderung der Einstrahlung) ändert sich die Wassertemperatur so, dass die Wirkung der ursprünglichen Änderung von Windgeschwindigkeit oder Luftfeuchte auf die Verdunstungsgeschwindigkeit teilweise wieder aufgehoben wird.

Bezeichnet E den Verdunstungsbetrag in cm./Tag, I die Einstrahlung in cal./cm.^{2}/Tag, B die Rückstrahlung im gleichen Mass, S die zur Erwärmung des Wassers verbrauchte Wärmemenge (in cal./Tag, bezogen auf eine Wassersäule von 1 cm.^{2} Querschnitt und einer Höhe gleich der mittleren Tiefe der verdunstenden Wassermasse), K eine Korrektion wegen der Wärmemenge, die als gefühlte Wärme zwischen Luft und Wasser ausgetauscht wird, C eine Korrektion wegen des Wärmeverlustes durch die Wände des Behälters, der Ausdehnung des Wassers und der Wärme, die gegebenenfalls durch die Strömung fortgeführt wird, und endlich L die latente Verdampfungswärme des Wassers, so gilt folgende Grundgleichung:

$$E = \frac{I - B - S - K - C}{L} \tag{1}$$

Wird das Verhältnis der beiden Wärmemengen, die das Wasser auf verschiedenen Wegen verlassen, der — durch den Wind entführten — gefühlten Wärme zur latenten durch die Verdunstung entführten Wärme, mit R bezeichnet, so ist $R = K/LE$, und die Beziehung von Cummings erhält die Form

$$E = \frac{I - B - S - C}{L\,(1 + R)}, \tag{2}$$

worin R empirisch zu bestimmen ist. Für R entwickelte Bowen die Gleichung

$$R = 0.46 \cdot \frac{t_w - t_a}{P_w - P_a} \cdot \frac{P}{760}, \tag{3}$$

deren Ableitung hier nicht weiter skizziert werden kann. Es bedeutet t_a die Lufttemperatur an der Luvseite des verdunstenden Wasserkörpers, t_w die Wassertemperatur, P den Luftdruck in mm., P_a den tatsächlichen Dampfdruck der Luft, P_w den Dampfdruck gesättigter Luft von der Temperatur des Oberflächenwassers, sodass R aus Faktoren berechnet werden kann, die leicht zu beobachten sind. Für die graphische Ermittlung von R hat Cummings in der "Monthly Weather Review", Band 58 (1930, S. 142—144) ein Diagramm veröffentlicht. Bei verschiedenen Bestimmungen von Richardson, die sich über alle Jahreszeiten verteilen und an einer Reihe von Beobachtungsorten in den westlichen Vereinigten Staaten ausgeführt wurden, lag R zwischen 0.17 und 0.28 und kann näherungsweise als konstant, zu 0.22, angenommen werden.

Cummings kommt zu dem theoretischen Ergebnis, dass die tatsächliche Verdunstungshöhe 42 bis 100 % derjenigen Menge beträgt, die verdunsten würde, wenn die gesamte eingestrahlte Wärme in latente Wärme umgesetzt würde, wenn also $EL = I$ wäre. Für die in der Praxis vorkommenden Verhältnisse sind die Grenzen wesentlich enger.

Aus der Gleichung (2) folgt

$$I - B = E \cdot L\,(1 + R) + C + S;$$

I hat für alle Wasserflächen bei gleichen äusseren Bedingungen denselben Wert; bei Parallelmessungen der Verdunstung von zwei verschiedenen Wasserkörpern, etwa einer Verdunstungsschale (Index 1) und einem Tank oder See (Index 2) wird

$$B_1 - B_2 + S_1 + LE_1\,(1 + R_1) + C_1 = S_2 + LE_2\,(1 + R_2) + C_2. \quad (4)$$

Ist die Differenz der Temperatur der beiden Wasserkörper kleiner als 15° C. — was wohl immer der Fall sein wird — so kann man unter Anwendung des Stefanschen Gesetzes über die Strahlung schwarzer Körper den Zahlenwert von $B_1 - B_2$ (in cal./cm.²/h.) in Gleichung (4) genügend genau als halbe Differenz der absoluten Temperaturen der beiden Wasseroberflächen einsetzen. Tatsächlich ergaben zahlreiche Parallelmessungen an einer Verdunstungsschale und einem kleinen und einem grossen Tank gute Befriedigung der Gleichung (4). Es würde sich also damit die Möglichkeit bieten, *mit verhältnismässig geringem Aufwand an Beobachtung und Rechnung* die Verdunstung von einem Tank oder See aus den Beobachtungen an einem in der Nähe aufgestellten Verdunstungsgefäss mit praktisch ausreichender Genauigkeit zu finden. Voraussetzung ist dabei, dass für S und C plausible Werte eingesetzt werden können, wie das bei den eben erwähnten Versuchen von Cummings und Richardson der Fall war.

Umgekehrt ist auch versucht worden (Richardson und Montgomery), mit Hilfe der Formel (2) aus der gemessenen Verdunstungshöhe die Strahlung I zu bestimmen, welche die Wasseroberfläche erreicht. Die so gefundenen Werte stimmten innerhalb 4 % mit den gleichzeitig durch Pyrheliometer gemessenen Werten überein. Für die Berechnung der reflektierten Strahlung diente die Beziehung $B = 0.906 \cdot a \cdot T_w^4 - 0.790 \cdot b \cdot a \cdot T_a^4$ wo T_w und T_a die absoluten Temperaturen der Wasseroberfläche und der Luft, a die Stefan-Boltzmansche Konstante, b ein Korrektionsfaktor (~ 0.9), da die Atmosphäre nicht wie ein schwarzer Körper zurückstrahlt, und endlich 0.906 und 0.790 zwei von Richardson selbst ermittelte Korrektionsfaktoren sind. Da S und C für einen See gering sind, so liesse sich die Verdunstung von einem See mit Hilfe folgender Formel berechnen:

$$E = \frac{I - 0.906 \cdot a \cdot T_w^4 + 0.790 \cdot b \cdot a \cdot T_a^4}{L\,(1 + R)}$$

Hierbei könnte I entweder durch Berechnung aus klimatischen Daten, durch Messung, z. B. mit dem Pyrheliometer, oder, wie oben angedeutet, aus Verdunstungsmessungen an einem Verdunstungsgefäss am Seeufer gefunden werden.

Als bemerkenswert für die Technik der Verdunstungsmessung auf See sei noch eine ausgedehnte Versuchsreihe auf dem weit in die See vorspringenden Pier des "Scripps Institute" in La Jolla erwähnt, bei der durch Messungen in drei verschiedenen Höhen bis zu 15 m. über dem Wasser der vertikale Gradient der meteorologischen Faktoren verfolgt wurde. McEwen kommt zu dem Schluss, dass für praktische Zwecke Beobachtungswerte aus jeder Höhe über dem Wasser gebraucht werden können. Die Strahlungswerte, die in der oben skizzierten Weise aus den Messungen an den drei in verschiedenen Höhen aufgestellten Verdunstungsschalen berechnet wurden, stimmten gut mit den pyrheliometrisch gemessenen Strahlungswerten im oberen Beobachtungsniveau überein. — Allerdings ist darauf hinzuweisen, dass das Meer vor La Jolla noch dem nordostpazifischen Auftriebgebiet angehört; vor einer einfachen Verallgemeinerung dieses Befundes ist daher m. E. doch zu warnen.

Aus einer derzeit noch nicht abgeschlossenen experimentellen Untersuchung von Cummings ist die nochmalige Bestätigung des eingangs bereits erwähnten Befundes zu erwarten, dass die Korrelation zwischen Verdunstung und Feuchtigkeit oder Verdunstung und Wind gering ist. Ferner

hat die Grösse der Verdunstungsfläche, die bei thermisch nicht isolierten Gefässen von merklichem Einfluss auf die Messung ist, bei Verwendung thermisch isolierter Gefässe sehr geringe Bedeutung.

Neben der einwandfreien Bestimmung der Verdunstung von Süsswasserflächen, die gerade in dem Klima der westlichen Union von grosser wirtschaftlicher Bedeutung ist (die in Kalifornien entwickelten Messungsmethoden haben einen rechnerischen Fehler von nur 3 %), hat McEwen als eigentliches Ziel dieses grossen Komplexes theoretischer und praktischer Untersuchungen die Messung der Verdunstung vom Weltmeer als fundamentales geophysikalisches Problem im Auge. Seine eigenen umfangreichen theoretischen und praktischen Vorarbeiten in dieser Richtung, die sich auf die kalifornischen und nordostpazifischen Gewässer erstrecken, werden im vorliegenden Bericht nur kurz gestreift; für die letzte dieser Arbeiten kann der Leser dieser Zeitschrift auf das Referat von H. Thorade in Band V, Seite 398—399 verwiesen werden.

A. Schumacher.

E. S. Nielsen. "Einleitende Untersuchungen über die Stoffproduktion des Planktons." Medd. fra Komm. for Danmarks Fiskeri- og Havunders. Ser. Plankton, Bd. II, Nr. 4. København, 1932.

Samples of water were drawn from depths of 0.2 and of 8 metres in the outer harbour of Frederikshavn, the depth of which is somewhat over 8 metres. These were filled into 100 cm.^{3} bottles, both clear and covered to exclude light. Those filled with water from 0.2 metres were suspended in the harbour at depths of 0.2 and 2 metres, and those filled with water from 8 metres at depths of 2, 5 and 8 metres. After 24 hours their oxygen content was determined by Winkler's method, a micro-titration of the iodine set free being used. The differences from the initial oxygen content gave a measure of assimilation and of respiration by the contained plankton, a mixture of both plant and animal organisms.

Assimilation was nearly the same at 0.2 and 2 metres, while at 7 metres in most cases it just sufficed to balance respiration. The oxygen production per litre also varied with the nature and abundance of the plankton, the amount of sunshine and the transparency of the water in the harbour.

It was calculated that, during the course of one 24-hour experiment, the oxygen production below each square metre amounted to 7.1 g. of oxygen, equivalent to the production of 6.7 g. of glucose.

H. W. H.

Bruno Schulz. "Einführung in die Hydrographie der Nord- und Ostsee." Tierw. d. Nord- u. Ostsee. Lief. 21, Teil. I.d_2. Leipzig 1932.

Its title defines the standard of this paper. Subject to the understanding of the commoner hydrographic terms and concepts, it should be useful to beginners in the hydrographic field of the North and Baltic Seas, or to marine biologists desiring a rapid, comprehensive view of the hydrographic "milieu" of these parts.

Essentially the paper consists of three sections:

1. The principal bathymetric features of (a) the North Sea, (b) the Kattegat, Belts and Sound, (c) the Baltic. The northern area of the North Sea is dismissed somewhat summarily under this head, there being one or two

shoals and banks quite worthy of mention, e.g. Viking Bank, Bressay Shoal, Fladen Ground. The last is, in fact, mentioned later in another connection, but without reference to its position.

2. The properties and movements of the surface waters. The sub-heads of this section are temperature, salinity and alkalinity, air-content (oxygen, nitrogen, carbonic acid), hydrogen-ion concentration, tides, residual (or drift) currents, storm tides ("Sturmfluten").

3. Properties and movements of the deep waters.

The paper contains 25 illustrations and the text is interspersed with a number of useful and interesting tables. A short list of literature which is not claimed to be at all complete is appended to serve as a guide for further reading.

J. B. Tait.

G. Wüst. Das Bodenwasser und die Gliederung der Atlantischen Tiefsee. Wiss. Ergeb. d. Deutschen Atl. Exped. auf d. Forsch.- u. Vermessungsschiff "Meteor" 1925—1927. Bd. VI, Teil 1, Lief 1. Berlin u. Leipzig, 1933.

In his discussion of the bottom water of the Atlantic Ocean, Wüst has used all available data and has, therefore, been able to give a comprehensive description of the character of the bottom water and to draw a series of important conclusions.

The main part of the Atlantic bottom water is of antarctic origin. In the western Atlantic Ocean the last traces of the antarctic water are found in 40° N., but on the northward course the temperature and the salinity of the water are increased by admixture of warmer and more saline deep water. The percentage of admixture in the different latitudes is determined. In the eastern Atlantic the antarctic bottom water penetrates by a direct route only to the Walvis ridge in 35° to 20° S., but through the Romanche channel in 2° N., which forms a gap in the Atlantic longitudinal ridge, antarctic bottom water flows from the western to the eastern Atlantic and spreads to the north and the south. To the south this bottom water can be traced to the northern boundary of Walvis ridge and to the north to 35° N.

Only small quantities of arctic bottom water enter the Atlantic Ocean and are found in the western Atlantic to the north of 40° N. and in the eastern Atlantic to the north of 35° N.

From the distribution of temperature and salinity Wüst concludes that the bottom of the Atlantic Ocean shows a series of ridges and deeps, some of which are not known from existing soundings. Wüst points out three ridges and four deeps in the western Atlantic and eight ridges and nine deeps in the eastern Atlantic.

The paper is accompanied by excellent charts, including a chart which shows the configuration of the bottom below a depth of 4000 metres as it appears when the character of the bottom water is considered.

H. U. S.

F. S. Russell. "On the Biology of Sagitta. III. A Further Observation on the Growth and Breeding of *Sagitta setosa* in the Plymouth Area; IV. Observations on the Natural History of *Sagitta elegans* Verrill and *Sagitta setosa* J. Müller in the Plymouth Area." Jour. Mar. Biol. Assoc. of the United Kingdom, Vol. XVIII, No. 2, Plymouth, 1933.

Mr. Russell has continued his investigations on the two species of Sagitta which are found in the Channel and the results are helpful. The

apparent history of Sagitta, like other forms of holoplankton, is a simple one. From the egg to the last phase it is borne by tidal and ocean currents, journeying hopefully onward without knowing where it is to arrive. The early feeding stages and the immature are dispersed, and this phase is indicated by the small numbers captured in the plankton nets. Then at certain periods of the year a congregation takes place of the mature and spawning occurs, and at these seasons the numbers recorded present a marked increase. The spawning behaviour indicates that the individuals are attracted to a zone of the current and it must necessarily be periodic.

The diagram which Mr. Russell gives of the history of *Sagitta setosa* for the first five months of 1932 is a continuation of a previous diagram in a previous paper and both illustrate these points clearly. Each year about May he got a pure sample of mature, and this was preceded by and succeeded by the occurrence of immature and small specimens. There is an indication of spawning by congregation and the condition of the specimens in or about September. A further factor therefore appears to control the event of the spawning and it is that while maturity is indicated by the condition of the gonads spawning does not take place until assembling has at all events begun. The remarkable feature is the apparent disappearance or almost complete disappearance of the young stages from the spawning zone. So complete a dispersion of the young was not seen in the case of *Sagitta elegans*, but still the results show that their numbers undergo a diminution. It is such cross-current migrations which make it difficult, as Mr. Russell has found, to arrive at data with regard to growth. It may be said also that it is this periodicity of events which controls seasonal abundance.

For the purpose of giving a picture of the vertical distribution of Sagitta Mr. Russell has examined collections made in 1926 and these indicate incidentally that, like the North Sea, the Channel was invaded by *Sagitta setosa* in that year. An attempt is made also to correlate the results with determinations of light intensity made at Plymouth. These species, like so many other forms, have their diurnal ups and downs and we have been content to regard the movement (which should not be termed a migration) as being a response to daily light changes. The fact is, however, that the movement is subject to individual variation, and all that can be said is that the young stages are more common at the surface and that *Sagitta setosa* tends to be more superficial in distribution than *S. elegans*.

A. M.

E. Fischer-Piette. "Répartition des principales espèces fixées sur les rochers battus des côtes et des îles de la Manche, de Lannion à Fécamp." Ann. de l'Inst. Océanogr. N. S., Tome XII, Fasc. IV. Paris 1932.

Die Arbeit enthält eine vergleichend-ökologische Übersicht über die Besiedelung an steilen, dem Wellenschlag ausgesetzten Felsen der Gezeitenzone. Die französische Küste am Kanal-Eingang wurde von Saint Malo aus nach Westen bis Roscoff und nach Osten bis Fécamp untersucht, ausserdem wurden die Anglo-Normannischen Inseln einbezogen. Im Ganzen wurde auf 60 Stationen beobachtet, die Daten sind alle vom Verfasser selbst gesammelt, sodass sie sich sehr gut vergleichen lassen, obwohl keine quantitativen Angaben gemacht werden. Die Grundlage bildet eine sorgfältige Einzelbeschreibung der Stationen mit ihren Standortsfaktoren und der Verteilung der Organismen auf die 3 unterschiedenen Vertikalstufen der Steilküste. Dann werden etwa 30 häufige Arten einzeln behandelt hinsichtlich ihrer Frequenz

und Abundanz. Dabei werden viele interessante Einzelheiten mitgeteilt, auf die wir hier nicht eingehen können, es sei nur auf einige Arten hingewiesen. Wir erfahren z. B., dass die Fucaceen an der exponierten Steilküste fehlen und dafür Cirripedien, Flechten und Rotalgen stark entwickelt sind. Über die Ökologie von *Himanthalia lorea*, der drei gut unterschiedenen *Patella*-Arten mit ihren Standortsmodificationen, der Cirripedien *Chthamalus stellatus, Balanus balanoides, B. perforatus, B. crenatus, Verruca strömia* und verschiedener Flechten und Rotalgen werden interessante Ergebnisse mitgeteilt. Der Einfluss der Gesteinsbeschaffenheit auf die Küstenform und auf die Besiedelung kann anschaulich gezeigt werden, da der westliche Teil des Untersuchungsgebietes aus Eruptivgestein besteht und im Osten die Sedimentgesteine des Pariser Beckens an die Küste herantreten. Andere Faktoren sind der Wellenschlag, die Tageszeit des Springniedrigwassers (Hafenzeit), der Gehalt des Wassers an gelöster organischer Substanz, die Feuchtigkeit, Besonnung u. a. m. Einige Arten zeigen eine geordnete Verteilung der Häufigkeit, welche noch nicht hinreichend erklärt werden kann. Verf. vermutet, dass hierbei auch die Biologie der Larven eine Rolle spielt, welche noch nicht näher untersucht wurde.

Die Arbeit ist ein anregender und wertvoller Beitrag zur Frage, welche Faktoren die Verbreitung und die Häufigkeit der Organismen an der Meeresküste bestimmen.

Hagmeier.

H. Blegvad. "Preliminary Report on the Danish Experimental Transplantations of Plaice from the North Sea to the Belt Sea during the Years 1928—31". Rep. Danish Biological Station XXXVII, 1932. Copenhagen, 1932.

Der Rückgang der Schollenfischerei in Kattegat und Beltsee veranlasste die dänische Regierung, durch grosszügige Versuche die Möglichkeit zu prüfen, ob durch Verpflanzung von Nordsee-Schollen in diese Gewässer der gesunkene Fischereiertrag wieder gehoben werden könne. In den Jahren 1928 bis 1931 wurden insgesamt 3,600,000 Schollen im Gewicht von 312,000 kg. im südlichen Kattegat und in der Beltsee ausgesetzt. Da sich beim ersten Versuche kein Unterschied zwischen Schollen aus dem Limfjord und solchen aus der Nordsee ergab, wurden zu den späteren Versuchen des kürzeren Transportes wegen ausschliesslich Nordsee-Schollen aus dem Horns Riff-Gebiet verwendet. Es erwies sich als zweckmässig, die Tiere nach dem Fange 3 Tage in Esbjerg zu hältern, damit sie den Darm entleerten und vor Verletzungen durch scharfkantige Muschelbruchstücke bewahrt blieben. Dann wurden sie im Kraftwagen nach Fredericia transportiert, wo sie nochmals 2 Tage lang in Fischbehältern gehegt wurden, bevor man sie an die Aussetzungsplätze brachte. Bei jedem Versuche wurden 2—3000 transplantierte Nordsee-Schollen und zugleich eine grössere Zahl einheimischer Schollen markiert. Die Leitung der Arbeiten lag in den Händen von Fischereidirektor M o r t e n s e n; die wissenschaftlichen Untersuchungen wurden in Zusammenarbeit mit der Dänischen Biologischen Station ausgeführt.

Der Prozentsatz der wiedergefangenen Tiere war normalerweise bei den einheimischen Schollen grösser als bei den verpflanzten Fischen, von denen doch offenbar ein Teil durch den Transport geschädigt worden war. So erhielt man nach dem 1929 vorgenommenen Versuche bis Ende 1931 60 % der Beltsee-Schollen, dagegen nur 32 % der Nordsee-Schollen zurück. Von den 1931 markierten Fischen wurden relativ mehr transplantierte als einheimische Exemplare wiedergefangen — 34 % gegen 24 % bis Januar 1932. Dies mag

seine Ursache darin haben, dass in jenem Jahre infolge Mangels an Beltsee-Schollen der erforderlichen Grösse — der in Betracht kommende Jahrgang 1929 war sehr arm — die Fische an verschiedenen Stellen gesammelt wurden und oft lange Transporte bis zum Aussetzungsorte durchmachen mussten. Die schädigende Wirkung eines weiten Transportes zeigte sich deutlich bei den nach entfernteren Plätzen gebrachten Nordsee-Schollen. Von den bei Fredericia ausgesetzten Tieren wurden 60 % wiedergefangen, hingegen von solchen im Sund und bei Langeland ausgesetzten nur 11—18 %.

Das Wachstum der verplanzten Nordsee-Schollen war ausgezeichnet. Sie massen beim Aussetzen 21—22 cm. und nahmen bis zum Ende des Jahres im Durchschnitt 10—12 cm. an Länge zu; das Stückgewicht stieg von 95 g. auf 300 g., war also mehr als verdreifacht. Die mittlere Grössenzunahme der einheimischen Beltsee-Schollen in der gleichen Zeit war um die Hälfte geringer, sie wuchsen nur 6—7 cm.

Die Frage, ob diese Verpflanzungen sich bezahlt machen, beantwortet Blegvad in bejahendem Sinne. Die Lieferung bis zur Aussetzungsstelle wurde einem Fischhändler unter bestimmten Bedingungen zu einem festen Preis für das kg. lebende Fische übertragen. Dafür wurden jährlich 40,000 Kr. aufgewendet. Im Jahre 1931 betrug die Zahl der verpflanzten Fische 1,190,000, die Unkosten pro Fisch beliefen sich also auf $3^1/_3$ Øre. Nimmt man gemäss den Markierungsergebnissen des Versuches vom Jahre 1929 an, dass ein Drittel aller verpflanzten Schollen wiedergefangen wurde bei einem Durchschnittsgewicht von 300 g., so ergibt sich, dass ein solcher Fisch mit 10 Øre belastet ist. Er brachte jedoch bei einem Marktpreis von 90 Øre für 1 kg. dem Fischer 27 Øre ein. Den Verpflanzungskosten von 40,000 Kr. stehen somit Einnahmen der Fischerei von 107,000 Kr. gegenüber. Die Gewichtsmenge an Marktschollen, die der Fischerei durch die Verpflanzung zugeführt wurde, war danach gleich derjenigen der ausgesetzten Schollen, nämlich etwa 115,000 kg., ein Betrag, der bei einer durchschnittlichen Jahresanlandung aus der Beltsee von 700,000 kg. beträchtlich ins Gewicht fällt. Vermutlich darf man den Prozentsatz der wiedergefangenen Tiere noch höher ansetzen, sodass der Gewinn noch grösser ist.

Eine unerlässliche Voraussetzung für die Rentabilität derartiger Transplantationen ist ein ausreichender Schutz der ausgesetzten Fische vor Nachstellungen, bevor sie beträchtlich herangewachsen sind. Man strebt deshalb für die Aussetzungsgebiete eine Schonzeit und ein höheres Mindestmass an und plant, die Fischer zu den Unkosten heranzuziehen durch Erhebung einer Abgabe (50 Øre pro P. S.). Eine Zusammenarbeit zwischen Dänemark, Schweden und Deutschland ist sehr erwünscht, bieten doch derartige Verpflanzungen, wenn sie in grossem Masstabe ausgeführt werden, die Aussicht, die nahrungsreichen, jetzt dünn besiedelten Meeresabschnitte der Beltsee und westlichen Ostsee wieder ertragreicher zu machen. Zur Ergänzung mag angefügt werden, dass auch in den Jahren 1932 und 1933 je ca. 1 Million Schollen in die dänischen Gewässer verpflanzt worden sind.

Es ist bemerkenswert, dass nach Beobachtungen im Winter 1931/32 die transplantierten Nordsee-Schollen bereits in der nächsten Brutperiode laichen. Sie werden sich also notwendig mit den einheimischen Schollen kreuzen, welche nach den Untersuchungen von A. C. Johansen einer von der Nordsee-Rasse unterschiedenen Form, der Baltischen Rasse, angehören. Man darf deshalb gespannt sein, wie sich bei fortgesetzter Zuführung von so beträchtlichen Mengen der Nordsee-Rasse die Rassenmerkmale der Nachkommenschaft des so gemischten Bestandes verhalten werden.

R. Kändler.

E. M. Poulsen. "Analyses of Stock and Race of the Baltic Plaice during Recent Years". Rep. Danish Biological Station XXXVII, 1932. Copenhagen, 1932.

Der Verfasser berichtet über Untersuchungen des Schollenbestandes der Ostsee während der Jahre 1927—31. Nach Darlegung der Alterszusammensetzung und der in den letzten Jahren beobachteten Fluktuationen erörtert er ausführlich Rassenanalysen aus verschiedenen Gebieten, auf Grund deren er zu dem Ergebnis kommt, dass eine beträchtliche Einwanderung von Schollen der Nordsee-Rasse aus dem Kattegat in die Ostsee stattfindet.

Wie schon A. C. Johansen zeigte, besitzt die Scholle der westlichen Ostsee die niedrigste Wirbelzahl (42.3) und Strahlenzahl in der Analflosse (50); dies Gebiet muss also vornehmlich als die Heimat der *Baltischen Schollenrasse* angesehen werden. Gegen Norden, in Beltsee und Kattegat, steigt die Wirbelzahl an, denn hier mischt sich die Baltische Scholle mit der aus dem Skagerak eindringenden *Nordsee-Rasse*, die gekennzeichnet ist durch höhere Werte für Vert. S. und A. (43 und 54). Doch auch nach Osten zu, in der eigentlichen Ostsee, beobachtet man eine Zunahme der Wirbelzahl; der von E. M. Poulsen mitgeteilte Mittelwert von 42.9 für Schollen aus dem Bornholm-Becken ist ebenso gross wie der an Schollen aus dem Skagerak gefundene. Die Strahlenzahl der Analflosse bleibt allerdings mit 51.2 erheblich unter dem Wert der Nordsee-Rasse. So sieht sich der Verfasser vor die Frage gestellt, ob diese hohen Werte einer Einwanderung von ausserhalb zuzuschreiben sind, oder ob sie spezielle Merkmale einer Schollenrasse dieses inneren Teiles der Ostsee sind. Da die bisher untersuchten zwei Proben (mit knapp 300 Individuen) noch kein sicheres Urteil gestatten, lässt Poulsen diese Frage offen, wenn er auch in Anbetracht der weiten Entfernung vom Wohnort der Nordsee-Rasse bis zum Bornholmgebiet der zweiten Möglichkeit zuneigt.

Dagegen gelangt er in bezug auf den Schollenbestand des westlich von Bornholm zwischen Rügen und Südschweden gelegenen *Arkona-Beckens* zu sehr bestimmten Schlussfolgerungen, die er vorwiegend auf Zählungen der Analflossenstrahlen gründet. Er findet hier einen Mittelwert von 51.9; dieser ist also höher als im Bornholm-Becken (51.2) und in der nördlichen Beltsee (51.1) und liegt nahezu in der Mitte zwischen den Werten der Nordsee-Rasse und der Baltischen Rasse. Das erhaltene Variationspolygon zeigt zwei Maxima bei 50 und 53, in denen Poulsen das Anzeichen einer gemischten Population sieht. Der erste Gipfel bei 50 gehört der Baltischen Rasse an, der zweite bei 53 der Nordsee-Rasse. Auch die Analyse von Schollenfängen aus dem Küstengebiet von Seeland, Møen und Falster lieferte eine bimodale Kurve mit dem Hauptgipfel bei 50 und einem kleineren Maximum bei 52. Für die benachbarten Meeresgebiete im Norden, Westen und Osten ergeben sich eingipflige Polygone, die abgesehen von derjenigen der reinen Nordsee-Rasse im Skagerak, durch eine geringe Asymmetrie eine nur geringe Vermischung anzeigen, und zwar in der Beltsee eine Beimischung von Schollen der Baltischen Rasse zur Nordsee-Rasse, in der westlichen Ostsee wie auch auf dem Bornholm-Rügen-Plateau umgekehrt eine solche von Nordsee-Schollen zur Baltischen Rasse. So wird aus der Form der Variationskurven geschlossen, dass "eine beträchtliche Einwanderung von Schollen (Eier, Larven, Jungfische) von ausserhalb nach den dänischen Küstengewässern von Seeland, Møen und Falster und nach dem Arkona-Becken stattfindet". Diese These wird weiter gestützt durch die Beobachtung, dass die mittlere Analflossenstrahlenzahl der Ostsee-Schollen in den Altersgruppen II und III grösser gefunden wird als in der O-Gruppe, namentlich in dem

Gebiet zwischen Falster und Bornholm. Da bei höheren Gruppen keine weitere Zunahme festzustellen ist, wird angenommen, dass vorwiegend jugendliche Tiere einwandern. Diese können nur aus zwei Gebieten in diesen Teil der Ostsee gelangt sein: Entweder aus der westlichen Ostsee über die Darsser Schwelle, oder aus dem Kattegat durch den Sund. Die erstgenannte Möglichkeit scheidet jedoch aus, da in der westlichen Ostsee die Strahlenzahl niedriger ist als in der eigentlichen Ostsee. Man muss also eine Einwanderung jugendlicher Schollen aus dem Kattegat durch den Sund annehmen. Diese müsste von der gleichen Grössenordnung sein wie die Bruterzeugung des Arkona-Beckens, wenn der relativ hohe Mittelwert der Strahlenzahl aus der Vermischung der beiden Rassen resultiert.

Die Deutungen, die P o u l s e n seinen Befunden gibt, bedürfen in mancher Hinsicht noch der Ergänzung und Nachprüfung durch weitere Untersuchungen. Er stützt seine Schlüsse z. T. auf ein nicht sehr zahlreiches Beobachtungsmaterial. Insbesondere liegen der bimodalen Kurve für die Strahlenzahl der Arkona-Scholle nur 133 Tiere zugrunde, sodass man im Zweifel sein darf, ob ihre Zweigipfligkeit nicht doch auf unausgeglichene Zufälligkeiten zurückzuführen ist. Damit würde aber die vorgetragene These ihre wichtigste Stütze verlieren, denn der hohe Mittelwert der Strahlenzahl allein beweist noch keine Rassenmischung. Erklärt doch auch P o u l s e n die hohe Strahlenzahl im Bornholm-Becken nicht durch Einwanderung von Schollen der Nordsee-Rasse. Die in der Arbeit mitgeteilten Mittelwerte der Wirbelzahl in den verschiedenen Gebieten vermögen nicht die Anschauung zu stützen, dass dem Schollenbestand des Arkona-Beckens eine Sonderstellung zukommt. Vert. S. wird im südlichen Kattegat, in der Beltsee, im Arkona-Becken und im Oderbank-Gebiet zu 42.7 gefunden, bei Møen und Falster zu 42.6. Dieses Merkmal zeigt also eine bemerkenswerte Konstanz. Am ehesten müsste sich noch die Rassenmischung in den westlichen Teilen der Ostsee, an den Ausgängen der Belte, geltend machen, durch die in weit höherem Masse als durch den Sund Eier und Larven von Tieren aus dem Kattegat zugeführt werden. Doch hier wurde gerade die niedrigste Wirbelzahl (42.3) festgestellt.

Die Verhältnisse in der Ostsee als einem Grenzgebiet der Verbreitung der Scholle liegen offensichtlich viel zu verwickelt, als dass man sie mit dem Vorhandensein zweier sich in wechselnder Menge mischenden Rassen erklären kann. Zur Lösung dieses Problems, das gerade seiner Besonderheiten wegen für die Rassenforschung sehr aufschlussreich sein kann, bedarf es weiterer ausgedehnter Untersuchungen vor allem über die Wirbelzahl. Ohne genaue Kenntnis der Schollenbevölkerung östlich von Bornholm kann die Frage, ob im Arkona-Becken eine gemischte Schollenpopulation vorliegt und welcher Art diese ist, nicht beantwortet werden.

R. Kändler.

A. Bückmann. "Ergebnisse der Kontrolle der Schollenbevölkerung der deutschen Bucht bis zum Jahre 1932". Ber. d. deutsch. wiss. Komm. f. Meeresforschung, N. F., Bd. VI, Heft 3. Leipzig, 1932.

Dr. B ü c k m a n n's report deals with the surveys of the plaice stock in the German Bight carried out by research vessels in the spring or summer of 1924, 1926 and 1929—1932. Many thousands of fish were measured and their age determined. From these data the density of the plaice population, fluctuations in the strength of year-classes, and variations in the rate of growth are correlated in a masterly manner, with the result that a very complete picture is presented of the changes in the plaice stock during the years of investigation and their effect on the German landings.

In order to do this it has, of course, been necessary to make certain assumptions and possibly it would have been better in a scientific report if Dr. Bückmann had contented himself with correlating the area density and age distribution of the stock with the commercial landings for the years when he had comparable data — that is to say, for 1931 and 1932 when a cover net was used in the experimental hauls and when the samples were taken at nearly the same season of the year — and had not tried to relate back the scientific to the commercial data on a somewhat insecure foundation. For example, much is deduced from the changes in the average growth-rate, yet when the material on which the growth-rate is calculated is examined, it is found that it was collected in months as widely apart as March and June. The difference of three months can have a material effect on the average size, and it is perhaps significant that the highest sizes (with the exception of the 1928 year-class) were found when the samples were taken in June, and the lowest when they were obtained in March. There can be no doubt, however, that in the case of the abnormally rich year-class of 1928 a slower growth-rate has been proved. Whether this was due entirely to overcrowding or partly to other factors cannot be definitely established until a correspondingly rich year-class again appears. It is not possible to say whether the differences in the months of sampling had an effect on the area density as but little is known of variations in the time of the migration from the coast from year to year.

Dr. Bückmann is very alive to the dangers of over-fishing the young stock just before it becomes marketable. He shows that this stock is more rationally exploited off the Danish coast and in the German Bight at the present time owing to the use of the seine by the Danes and of a wide-meshed net by the German cutters, whereas previously the fishing had been carried on mainly by the steam trawlers. Both methods are certainly more sparing of undersized fish than the net used by steam trawlers, nevertheless the protection afforded by the cutters cannot be considered as ideal, since only 17 % of the catch in the samples was over 23 cm. in length and therefore of marketable size.

The conclusion that future developments of the plaice fishery must be watched carefully is very sound, and the lines on which Dr. Bückmann and his colleagues are working are admirably suited for the purpose.

D. E. T-P.

J. Lundbeck. "Untersuchungen über die deutschen Schollenanlandungen aus der Nordsee, insbesondere über die Anlandungen der Hochseekutter in den Jahren 1930 und 1931". Ber. d. deutsch. wiss. Komm. f. Meeresforschung. U. F., Bd. VI, Heft 3. Leipzig, 1932.

This report shows a notable advance in our knowledge of the marketable stock of North Sea plaice. The area fished by German vessels is not large but it is of particular importance, as it includes much of the principal young plaice grounds. Dr. Lundbeck describes the sorting of plaice and evaluates the landings of marketable plaice according to size and age. He has taken into consideration, not only his own market material, but the results of Dr. Bückmann's research vessel work in order to correct or confirm his conclusions.

The work reported on began in May 1930 and ended in October 1931. Samples were taken at Wesermünde in most months and occasionally at Hamburg, Altona and Cuxhaven. Over 8,000 fish in 1930 and twice the number in 1931 were measured and otolithed.

Sorting is by no means uniform on the different markets and even on the same market there is much variability. The sorting of plaice landed by steam trawlers also differs from that landed by cutters but, since the great bulk of the landings are from cutters, this difference is not important; consequently Dr. Lundbeck's samples were taken therefore mainly from the cutters.

Plaice landed dead at the ports are sorted regularly into four categories (Sorte I—IV); at times a fifth, of smaller fish, is landed. The majority of the landings are of Sorte IV, which has a range of about 21—37 cm., the mean being between 25 and 27 cm.; very few plaice, however, are regarded as marketable below 23 cm. 41 % of the landings, however, are of live plaice whose average size is slightly smaller than Sorte IV. These two — live and Sorte IV — together account for 90 % of the landings.

That very small plaice are not in demand in Germany is well shown in Table 7, where samples from cutters which landed their entire catch are analysed. The undersized plaice were for the fish meal factories and only 19.5 % of the catch was sorted as marketable. Many of the plaice were rejected for the market below 26 cm., and not till the plaice had reached the VI-group was an entire age group retained. Fortunately the landing of undersized plaice by cutters is of rare occurrence and it is probable that many are returned to the sea alive since so much of the fishing is for "live" plaice. Nevertheless, since it requires great care to prevent injury to plaice when using the trawl, it must be conjectured that the destruction just before they reach marketable size must be considerable.

Individual weighings of fish were not undertaken, but the number of fish in 50 kg. of each category was calculated. These data together with the measurements and age determinations were applied to the total landings of plaice by the cutters. In this way it was shown that the IV-group predominated; the V- and III-groups coming next in importance; the former in the first half and the latter in the second half of the year. Stress is laid on the fact that the part played by the III-group depends on the rate of growth as well as the strength of the year-class. An estimation was made of the rate at which the number present in each age group decreases from year to year. As the work has only been carried out for two years, this needs further confirmation before it can be regarded as reliable.

Dr. Lundbeck is to be congratulated on a bold piece of work and it is hoped that the investigations will be continued, since they are essential for the purpose of keeping a check on the stock of marketable plaice.

D. E. T-P.

C. Segerstråle. "Über scalimetrische Methoden zur Bestimmung des linearen Wachstums bei Fischen, insbesondere bei *Leuciscus idus* L., *Abramis brama* L. und *Perca fluviatilis* L." Acta Zoologica Fennica 15. Helsingfors, 1933.

Die vorliegende Arbeit ist methodisch bedeutsam. Sie beschäftigt sich mit der vielfach angewendeten, von Dahl und Lea entwickelten Methode, den Zuwachs der Fische aus der Breite der Jahreszonen auf der Schuppe zu berechnen. Es ist bekannt, dass sich dabei in vielen Fällen Unstimmigkeiten ergeben. Die Längenmittel für junge Altersgruppen werden zu klein, wenn sie aus den Schuppen älterer Fische errechnet werden. Lee hat dies als "apparent change in growth rate", verändertes Wachstum, bezeichnet. Mehrere Erklärungen und verschiedene Korrektionsmethoden dafür sind vorgebracht worden.

Verf. weist darauf hin, dass L e a die Proportionalität des Wachstums von Körper und Schuppe beim Hering für den *dorsoventralen* Durchmesser einer Normalschuppe nachgewiesen hat, dass aber für die Messungen und Längenberechnungen der oral vom Schuppenzentrum gelegene Abschnitt des *Längsdurchmessers* benutzt wird, der, wie M o l a n d e r nachgewiesen hat, nicht genau proportional zum Körper wächst.

Es wird sodann nachgewiesen, dass bei den drei im Titel genannten Arten der Längsdurchmesser der Schuppe und dessen oraler und caudaler Radius nicht proportional zur Körperlänge wachsen. Das wird bewiesen durch Messungen an Normalschuppen, die an bestimmter Stelle der Körperseite genommen werden. Die Schuppe wächst entweder dauernd oder doch anfangs schneller als der Körper. Das Missverhältnis ist beim oralen Radius sehr gross, beim caudalen dagegen viel kleiner, sodass man z. B. bei *Leuciscus idus* durch Messung des caudalen Radius ziemlich richtige Resultate erhält. Bei Messung des oralen Radius erhält man aber sehr deutlich "verändertes Wachstum", das demnach auf einen *methodischen* Fehler zurückzuführen ist. Die Korrektion durch eine additive Konstante, wie verschiedene Autoren sie vorgeschlagen haben, führt auch in diesem Falle zu einer Verbesserung der berechneten Längen. Doch hat die Grösse der Konstante nichts zu tun mit der Körperlänge bei der Anlage der Schuppen.

Der Verf. schlägt nun eine viel besser begründete Korrektion vor. Er verwendet dazu sein grosses Material von zusammengehörigen Körper- und Normalschuppenmessungen in folgender Weise: Die Schuppengrössen werden als Ordinaten in einem bestimmten Punkt der Abscisse eingezeichnet. Von einem anderen festen Punkt der Abscisse werden Strahlen durch die Endpunkte der Ordinaten gezogen. Auf jedem Strahl wird der Punkt gesucht, der von der Abscisse den Abstand hat, der der mittleren Körperlänge bei der gegebenen Schuppengrösse entspricht. Wären Schuppen- und Körperwachstum einander durchaus proportional, so würden alle diese Punkte auf einer Parallelen zur Ordinate der Schuppenlängen liegen, denn durch ein Strahlenbüschel werden parallele Geraden in proportionale Abschnitte zerlegt. Da aber keine geradlinige Proportion besteht, so liegen die gesuchten Punkte auf einer von der Parallelen abweichenden gekrümmten Linie, der "Korrektionskurve". Da die Schuppe anfangs schneller wächst als der Körper, so hat die Korrektionskurve für kleine Längen grösseren Abstand von der Ordinate als für grössere Fische.

Die Korrektionskurve kann nun, ganz wie bei L e a der parallele Masstab, zur geometrischen Bestimmung der Fischlänge zur Zeit der Bildung der einzelnen Winterlinien benutzt werden.

Das Verfahren setzt allerdings eine beträchtliche Vorarbeit für jede Art (vielleicht auch für jede Rasse, jeden Wachstumstyp?) voraus, liefert aber dann einwandfreie Korrektionen. Wo biologische Selektion die Ursache des "veränderten Wachstums" ist, wird es durch diese Korrektion nicht verdeckt.

A. Bückmann.

L. Beaugé. "Rapport de mission au Groënland (campagne 1931)." Rev. des Trav. de l'Off. des Pêches Mar. T.V, Fasc. 1, No. 17, Paris, 1932.

The author of this report adduces further, but naturally still incomplete, evidence in support of his bold and important hypothesis of correlation between the succession of events in the spheres of meteorology, hydrology and the fisheries. We witness an attempt to fill in supporting data for the validity of the lesser phases of the range (4½—9—18—111 years, in relation to sunspot variation), hitherto drawn attention to by L e D a n o i s and linked

to the variations in the time of occurrence of warm and cold transgressions in the northern hemisphere. The author traces these variations to their meteorological sources, defining four cold and four warm regions (anticyclonic zones and zones of depression) in the northern hemisphere, and showing how the displacement of these centres during the year determines the chief air movements, which in turn, directly and indirectly, have a considerable influence on the movements of water masses. There occur quite a number of different combinations of the effects of ordinary superficial summer heating of the water and of cold (from the north) and warm (from the south) water influxes, or transgressions, into the Newfoundland—Greenland area. The most constant factor is that of the solar heating of the surface layers; in the north, at Greenland (and probably also at Jan Mayen and Spitzbergen) the water becomes suitably warm for large masses of cod only during alternate periods of 4½ years when solar heating synchronises with a strong northerly transgression of warm water of Atlantic origin. It is claimed that this has occurred at regular intervals, the most recent favourable period being from 1927 to 1930. A progressive delay in the time of incidence of the warm transgression led, in 1931, to the occurrence of the latter near the close of the year — too late to combine with the ordinary summer-heating effect. The 1931 fishing season was therefore a short one; trawler catches diminished by 30 %, since water conditions soon became too cold for cod. The author's forecast that this would occur was therefore borne out, and he anticipates diminishing fishery returns from Greenland, and increasing returns from the Newfoundland area, during the ensuing 4½ years. In other words, good periods for the cod fishery alternate between Greenland and Newfoundland and can be anticipated. In contradistinction to what must occur at Greenland in order that a good fishery may ensue, the most favourable conditions exist at the more southerly latitude of Newfoundland when the influx of cold water from the north is in sufficient volume to temper the warmer and more regular influx from the south. The catches of cod are greatest in years when the combined heating effect, so favourable at Greenland, is absent, and when lower average temperatures are maintained. The author anticipates that the period 1932—1935 will be favourable at Newfoundland. The abundance of cod, he states, is bound up with that of the polar water in the Newfoundland region. Cod spawn in water having a temperature of between 3° and 5° and a salinity between 33 and 34 $^0/_{00}$. Such water last abounded in the period 1923 to 1926. In 1927 the warm transgression greatly exceeded the cold in effect, and polar water remained deficient in amount till 1931. A period of remarkably mild winters occurred at Newfoundland.

The author favours the view that great masses of cod move from Newfoundland to Greenland when conditions become more favourable in the latter than in the former region. It is essential to confirm this theory by tagging experiments. Tagging experiments off the coast of the United States have tended to show that cod populations are largely localised, and this finding can be supported, at least for young and medium-sized fish, by biological evidence, which does however leave room for deducing that there are very extensive migrations made by large cod. Such movements have recently been demonstrated by tagging to occur between Greenland and Iceland, and the author neatly shows that the migration became more intensive as conditions at Greenland became less suitable. Since a return migration to Greenland can occur, this is not merely a general northerly migration with increasing age.

If in places the specific evidence is on the weak side that the yield of

cod agrees entirely with the author's forecasts and what is to be expected of certain hydrographic conditions, he is to be congratulated on giving us a hypothesis which is broadly applicable and something of a godsend to the practical fishery biologist.

H. T.

L. Verbrugghe. "Die belgische Seefischerei." Handbuch der Seefischerei Nordeuropas, herausgeg. von H. Lübbert und E. Ehrenbaum. Bd. VII, Heft 3, E. Schweizerbart'sche Verlagsbuchh., Stuttgart, 1932.

It is well known that in earlier times the sea fisheries of the two countries which are now separated, Belgium and Holland, were similar, if not identical. In Flanders we find in later mediaeval times the same relation with the powerful Hansa League and the same active part in the Skania fishery as in the Dutch province of Zeeland; indeed, Flanders took the lead in this line. At a time when Ostend scarcely existed Newport was the principal fishing port. The discoverer of proper herring curing, Beukels, belongs, it would seem, as well to Flanders as to Holland. In the fifteenth century Belgium had herring busses similar to those in Holland.

From the year 1579, when the northern provinces in their revolt against the Spanish King declared themselves independent, the Flandrian fisheries took a different — and on the whole downward — trend owing to political difficulties. In the repeated wars the Flandrian fishermen took to privateering and piracy. The peace of Münster (1648) was disastrous to the Southern (then Spanish) Netherlands; the Scheldt and the Zwin (which silted up) were closed to their subjects, and in the later part of the seventeenth century Dunkirk, the cradle of rather lucrative sea-roving in these troublous times, was taken by the French. Newport was doomed to unimportance, and Ostend occupied herself occasionally with some whaling. Under the sway of Austria, to which the Southern Netherlands had fallen in the beginning of the eighteenth century, some efforts were made to revive sea fisheries by instituting prohibitive tariffs on foreign imports of fish. Yet there was always some drift net fishing in the North Sea and line fishing at Iceland. After the Napoleonic wars Belgium was incorporated in the kingdom of the Netherlands. In this period the beam trawl was introduced at Ostend; protestations in Holland against this new method brought about a close time from November 15th to February 15th in this country, but were ineffective in Belgium.

After the separation of 1830 a slow improvement began, and premiums for sea fisheries were instituted (up to 1500 fr. for herring busses). Small coastal vessels, fishing for autumn herring, were allowed by a special license to cure their herrings as the busses did, so they were not strictly excluded from doing so, as was the case in Holland. Premiums were abandoned in 1867.

Towards the close of the nineteenth century the Belgian fishermen, who were excessively poor, found it necessary to engage their wives and children actively in all sorts of industries, to raise the meagre earnings. The first small steam trawler was introduced into Ostend in 1884, but the gradual development of steam trawling, beneficient though it was to the sturdier fishermen, was on the whole a blow to the modest sailing craft.

During the war years many Belgian fishermen emigrated to England and made accquaintance with new fishing grounds. After the return of peace a rapid development set in. The number of steam trawlers, which was 24 in 1919, increased to 57 in 1928, then fell, however, to 36 in 1931. Motor

cutters numbered 17 in 1919 and rose to 401 in 1929, whereas sailing vessels practically disappeared. The ancient types of "koggen" (undecked clinker-built vessels), "sloepen" and "scuten", had already died out in the nineteenth century. Neither did "cingelnets", drawn between two vessels, seines, "stroopnetten" (stow nets) and the beam trawl survive the requirements of modern times; the two latter nets are, however, still used locally, in fishing for sprats and shrimps. Drift net fishing seems to be practised only by fishermen of La Panne.

A great handicap to the steam trawlers (whose only port is Ostend) is the lack of able fishermen, as the younger generation seems to take to other business ashore. And this in spite of the fact that, as early as 1906, a fishery institution for educating sailors' orphans was established on board an instruction vessel ("Ibis").

The enlargement and improvement of the fishery port of Ostend was begun in 1922 and is even now still incomplete. A new dock for steam trawlers is being built, with a length of 800 m., a breadth of 125 m. and a depth of 5 m. The new auction hall has a length of 366 m.

Apart from the education of pupils for sea fishery there are institutions for the protection of old fishermen, regulations for sea-going vessels, social laws etc.

All fisheries administration is centred in a special department of fisheries (since Oct. 1927), belonging to the Merchant Shipping department, which itself is a part of the Ministry for Traffic.

J. J. T.

S. T. Lindsay and **H. Thompson.** "Biology of the Salmon (*Salmo salar* L.) taken in Newfoundland waters in 1931". Reps. of the Newfoundland Fish. Research Comm. Vol. I, No. 2. Plymouth, 1932.

This Report on the examination of upwards of 4,000 sets of scales of salmon caught during 1931 in Newfoundland waters is a notably useful contribution to the literature on the subject. The object of the investigations is to elucidate the facts regarding the life history of the fish and therefrom to estimate the prospects for future seasons in relation to the colony's salmon fisheries, which have lately acquired an enhanced importance by reason of the adoption of the brine freezing process and the consequential creation of profitable markets abroad. The material handled is as yet of course inadequate for definite conclusions to be drawn, but the initial evidence so far obtained is of interest.

The fish (4,017 in number) from which the scales were obtained were taken mostly by nets in tidal waters at the various stations round the coast of Newfoundland, but they included 193 sets from the juxtaposed coastal waters of Labrador across the Straits of Belle Isle and 100 from rod-caught fish out of about thirty-six rivers. Out of a total catch of upwards of 200,000 fish the quantity sampled is perhaps hardly to be regarded as a truly representative collection, especially in view of the fact that 3.161 of these samples were procured from one station (St. Anthony) in the north-eastern part of this island. The difficulty of communication and the shortness of the season are circumstances which militate against the making of such a collection.

There are two recognised runs of salmon each year, viz., a winter and a spring run. The former is restricted in quantity and duration and is confined entirely to the Avalon Peninsula in the south-eastern corner of

the island. It is in evidence for a period of hardly more than a month, from mid-November to mid-December; and the fish of which it is composed are evidently not at that time of year on their way to any river. By far the most important run is what is known as the spring run, which begins some time during the latter half of May in the south, extending north to the Labrador coast by the end of June. It, also, is of short duration, rarely lasting more than three weeks at any one station. It provides not only the bulk of the annual harvest, but the whole of the season's breeding stock. Practically all the material was supplied by the fish of this run, and it is grouped geographically according to the stations at which the fish were caught, that is to say, Western, Southern, Eastern and Northern (the last named including the Labrador coast and the north-eastern stations of Newfoundland).

The information elicited is presented in 14 Tables (with explanatory notes) and is discussed in the text. There are also a number of informative photographs of typical scales. Incidentally, it is to be noted that the scales were taken from the caudal peduncle in the region of the adipose fin and as close as possible to the middle line — departing from the usual practice of selecting the scales from the shoulder — the justification submitted for this being that scales are first formed in the caudal region, are larger and depict most fully the life history of the fish. The usual magnifying projector and Lea's method of length calculation by scale measurement were employed.

The salient facts as ascertained are as follows:

(a) The great majority of the fish — as in the Eastern Atlantic — are maiden fish. The proportion of fish with spawning marks, however, is comparatively high, viz. 16 %, and of these 2.8 % had spawned twice or more often (three examples showing three spawning marks and one no fewer than four — the last mentioned being a fish of 14 years of age, on its way to spawn a fifth time and the oldest Atlantic salmon of which there is any record). The largest percentages of previously spawned fish occurred in the south (50 %) and west (30 %) coast groups.

(b) All the sea-year's categories recognised in European waters occur. The largest proportion (90 %), however, consists of the 2 and 2+ (small spring and summer fish) categories. The 1+ (grilse) is comparatively small (not quite 7 %) though at the south coast stations grilse preponderate (80 %) and at one eastern station (Notre Dame Bay) the percentage is high (50 %). The 3+ category (large spring and summer fish) is of insignificant dimensions, being less than 3 %, no samples occurring from the south coast and only one fish (previously spawned) from the west coast, while there are only three samples of the very large spring fish category (all of them having previously spawned).

(c) The general average weight of the fish is between 10 and 12 lb., very few exceeding 18 lb. or less than 7 lb. This would naturally be expected in view of the great preponderance of the 2 and 2+ categories (especially the 2+). The quality of the fish seems to be exceptionally good, judging by the length measurements and corresponding weights given in Table 2, the condition factor being in no case lower than 38, generally above 45 and, in some cases, as high as 60.

(d) The average duration of parr life is four years. It is longer in the northern rivers (in the Labrador rivers 35 % showed five years and 6 % as much as six years) than in those of the south and west, where three years is more usual. The number of 2-year old smolts amounted to only 5 %, while the 1-year old class was confined to one solitary specimen.

(e) The average size of the smolts is about 17 cm. (6.8 inches) being slightly more (18 cm.) in the Labrador specimens and slightly less (16 and 14 cm. respectively) in those of the south and west. The size varies comparatively little in any one area and it seems to be more or less independent of age. Contrary to what might have been expected, the Labrador smolts, in common with those of the eastern Newfoundland rivers, show a more rapid growth-rate and attain a larger size than those of the southern and western areas. Some remarkably large 4-year and 5-year old specimens (12½ to 13½ inches long) were attributable to the St. Anthony area (in the extreme north-east of Newfoundland).

(f) As regards marine growth, there is some evidence — not particularly strong — that after a comparatively short parr life there is a tendency to remain longer in the sea. There are too few of the large spring and summer and very large spring fish to justify a definite opinion on this point. The growth-rate of grilse appears to be fairly uniform in all cases, whatever may have been the term of years spent in the river as parr. In the case of the 2+ and 3+ categories, however, the growth-rate in the sea is in inverse proportion to the number of years spent in the river, the oldest smolts making the poorest growth subsequently. The marine rate of growth diminishes fairly regularly from the south to the north. The best first year's growth is made by the 3+ category and the poorest by the grilse (due to returns as such).

In the latter part of the Report the possibility of foretelling good and bad seasons is considered and the grounds of a hypothesis regarding the factors which may determine the movements and growth-rate of salmon in the sea are discussed, but in view of the short time occupied by the investigations and the limited data so far available, opinion must necessarily remain for the time being of a tentative character.

T. E. P-T.

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Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. Allen's Selected Bibliography published in Vol. I, Nos. 1 and 2 of the Journal, and since reprinted (Price, 1 Kr.).

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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